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INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

ENLARGED MEETING OF THE PERMANENT COMMISSION
(LISBON, 1949.)

QUESTION I.

a) Mechanisation of the maintenance and renewal of the permanent way.

b) Recent improvements relating to reinforced concrete and prestressed concrete sleepers.
Results obtained.

c) Recovery and strengthening of metal bridges that have reached the theoretical limit of safety.

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REPORT

(Belgium and Colony, Bulgaria, Denmark, Spain, Finland, France and Colonies, Greece, Hungary, Italy, Luxemburg, Norway, Netherlands and Colonies, Poland, Portugal and Colonies, Rumania, Sweden, Switzerland, Czechoslovakia, Turkey and Jugoslavia),

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The investigation which we have carried out in conjunction with various Railway Administrations on the question of the recovery and strengthening of metal bridges which have reached the theoretical limit of safety considered mainly three groups of questions.

The first group dealt with in Sections I, II and III of the questionnaire, is :

What is the extent, as regards tonnage, of metal railway bridges which cannot be retained without reconditioning?

What rules or regulations are applied to decide whether it is necessary to alter them?

Are these rules completely satisfactory or is it desirable to substitute others which would reduce costs or increase safety?

The second group (Sections IV and V of the questionnaire) relates to the technical methods employed in reclaiming or strengthening bridges.

Finally the third (Section VI of the questionnaire) sums up the considerations on which the decision to replace or reinforce a bridge is made.

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A. — Relative importance of metal bridges. — Causes making it necessary to alter them. — Regulations concerning the limit of safety.

The relative importance of metal bridges on the railways varies naturally a great deal with the geographical situation of the railway systems. We can get some idea thereof by making a comparison between the tonnage of the bridges and that of the rails on the main lines : the ratio between them varies, according to the information collected, from 10 to 50 %, the average being about 17 %. Small bridges (less than 10 m. = 32′ 9¾″ span) which are far and away the most numerous, only account for 20 % of the total. The important tonnage is provided by the average and large bridges.

How long do metal railway bridges last? A long time, 80 years or more, if they have been well made and well looked after. But they are built for definite loads, and as the additional loads to which they are subjected continue to increase all the time, there comes a day when it is necessary either to replace them or to strengthen them. The tonnage of metal used for this purpose every year is on the average 1/50th of the total tonnage; replacements account for the greater part of it : 4/5.

Amongst the causes which make it necessary to replace or strengthen bridges, the principal is the progressive increase in the weight of the trains and of the locomotives which are continually becoming heavier in order to develop greater power and be easier to maintain. The introduction of a series of very high powered engines on the main lines leads not only to the strengthening of the bridges on the lines in question but also to those on lines of lesser importance to which the heavy engines replaced by the new ones will now be diverted, and also to those on the secondary lines where the old engines also will be replaced by those now becoming available from the other lines. The preparation of the financial balance sheet when introducing a new series of engines should not overlook the cascade effects of diverting existing engines made available to other lines.

Other reasons for scrapping or strengthening metal bridges (old age, rust, alteration of the location of the line or route taken) are far less serious than the increase in loadings.

It sometimes happens that a very slight increase in the load is sufficient to remove a bridge from the « good » category to the « weak » category. This is due to the general use of safety regulations based on the rules for new bridges.

In the case of the latter, the laws of the country as a general rule lay down how the stresses in the various parts under typical load are to be calculated and compared with a limiting stress which, in most recent regulations, in the case of mild steel, is approximately half the limit of elasticity. The typical

train is usually heavier than the actual trains, the limit allowed is not always reached, and a new bridge can carry heavier overloads than those usual at the time it is built; some regulations even allow without making special checks overloads exceeding the weight of the typical load by 1/10.

When the overload however definitely exceeds that for which the bridge was built, a special check becomes necessary. In some countries there are no special regulations about this, the railways have drawn up general safety regulations which they adapt according to the needs; in other countries, the law lays down very strictly what checks are to be made. The methods of calculation are defined as in the case of new bridges, so that two main points have to be defined : the overload to be taken into account and the limiting stress to be allowed.

The overload can either be taken as deriving from the typical train on new bridges by a percentage of reduction of the weight of the wheels varying according to the category of line, or as equal to the effective estimated overload. The use of the effective overload is natural when it is question of an exceptional train; that of an overload covering all immediate requirements is better in other cases.

In the case of the limiting stress, many countries retain that applicable to new bridges (sometimes with certain simplifications in the calculations); others increase it by 1 or 2 kgr./mm^2 (0.6349 or 1.269 tons per sq. inch) : while others again fix it as a definite fraction of the limit of elasticity or breaking strength of the metal of which the bridge is built. The latter formula would appear to be a wise choice, especially in the case of very old bridges, the metal of which is not always comparable to that of new bridges, either because manufacturing processes have been perfected (steel) or because manufacture has been given up (iron). When 2/3 of the limit of elasticity is taken, the limiting stress does not fall below 14 kgr./mm^2 (8.889 tons per sq. inch) in the case of iron and 18 kgr./mm^2 (11.43 tons per sq. inch) in the case of steel, values currently allowed in France for example, and which allow the life of bridges to be considerably increased; the calculations of the old iron bridges were often based on a limiting stress of 6 kgr./mm^2 (3.809 tons per sq. inch).

On certain Railways the stress under a given load obtained by calculation is replaced by a more accurate figure obtained by observations taken on the bridge. The deformations to which the stresses give rise are measured by means of extensometers of various types; the working stresses are deducted from the coefficient of elasticity of the metal. It must not be forgotten however that if the calculations are incomplete, the measurements can involve errors. When the tests are carried out carefully by skilled operators, the differences are nearly always due to housing badly estimated or to relief of the stresses in details by secondary elements, the influence of which has been overlooked in the calculations; measurements make it possible to recognise the extent of encastrement and the load carried by the secondary elements and to take them into account. But it is essential to check the calculations and repeat the experiments until reasonable agreement is reached between the two sets of results, and not to rely too much on the extensometer readings. Certain regulations have prevented a misinterpretation of the stress measurements by only taking them into account when the theoretical stresses do not exceed the limiting stresses by more than 20 %; this prudent rule as to the interpretation of the measurements seems to correspond very well to the permissible differences between the results obtained by reliable calculation and by trustworthy measurement.

The calculated and measured stresses often include a dynamic majoration coefficient laid down by the Regulations for new bridges, which differs from that which would be obtained if the respective stresses could be compared at the point in question, at rest and under the most unfavourable speed allowed. This shows the usefulness of taking measurements under loads at speed in order to find out the true coefficient. Certain Railways (Holland, Switzerland, France) have made such measurements; their interpretation is a much more delicate matter than static observations, but they are essential in order to appreciate the true stresses to which the metal is subjected.

Theoretical safety can be defined generally for bridges by the relation : stress $<$ limiting stress.

On the one hand the Railways are endeavouring to find a more precise definition for the former (more advanced calculations, actual experiments), and on the other to raise the second (increase relatively to the limit applicable to new bridges, definition as a percentage of the effective elastic limit of the metal). The progress achieved during some dozen years in this direction has made it possible to retain bridges which formerly would have been considered too weak.

Naturally these considerations are completed by others concerning the situation and the state of repair of the bridges. If, owing to faulty maintenance, a bridge shows certain sectional weaknesses, the correct section is substituted for the theoretical section; if any slackening of the assembly is observed, it is made good, whatever the results of the calculations concerning it; if the oscillations when trains run over at speed are found to be too great, the permitted speed is reduced, etc. As the maintenance services of the Railways know there are bridges which could not be passed by calculation alone.

The theoretical safety regulations are precise. But it is often very inconvenient to apply them. Some unusual traffic may have to be worked, a diversion of traffic or a relief train must be provided for; most often the traffic will be but little heavier than that already authorised, and will only be for a short time. In such cases many Railways make allowances such as an increase of 10 or 20 % in the limiting stresses allowed, various reductions in the dynamic increase for reduced speeds.

It is difficult not to allow such tolerances and still more difficult to withdraw those allowed under stress of circumstances; but they all take it for granted that the theoretical safety regulations are too pessimistic and can be exceeded sligthly without serious drawbacks. Consequently would it not be better to revise them and make them conform more closely with the real conditions of safety?

* * *

An endeavour to improve the existing regulations gives rise to the double question of defining safety in terms of metal bridges and the possibility of recognising a priori if safety has been assured.

These two points have been debated at the last Congress of the International Association of Bridges and Structures where there was seen to be a very definite tendency to define the safety offered by a bridge by the probability of its being put out of service within a given time for a given overload. The investigations and trials made lead us to think that this probability is not outside the scope of calculations, it being only necessary to fix its limiting value (10^{-5} or 10^{-6} for example).

Without anticipating the results of these investigations, it will be seen that to appreciate the real security offered

by a bridge two factors are involved : the first defines the signs by which it is possible to judge that it is unable to meet the demands imposed on it, and the second what conditions of overload will produce such signs.

The criterion for withdrawal from service varies from Railway to Railway. The breaking of an important part is obviously considered so by all, but this is not so as regards the appearance of permanent deformations or unusual elastic deformations. On most Railways we find bridges with very visible vertical deformations, the girders for example being permanently slightly curved, without it being considered necessary to strengthen them for the traffic they have to carry. On the other hand, certain bridges show signs of excessive elastic deformations under overload, either because they exceed those calculated or because they have a bad effect on the running of vehicles at high speed. Sometimes, vertical or horizontal oscillatory movements appear at a certain speed of sufficient intensity to upset the running of trains.

We are not overlooking the fact that the behaviour of bridges under overloads, the precise extent of the deformations which they undergo and the examination of their effects upon the profile and alignment of the track, must always be taken into consideration in determining safety criteria, whereas permanent moderate deformations, which have become stable in character, the origin of which is known, need not necessarily mean that the strength of the bridge must be considered as doubtful.

It remains to determine, according to the characteristics of the materials involved, the stresses and deformations resulting from an overload. These depend upon the design of the bridge and the quality of the metal. In the case of new bridges, the conditions of acceptance now imposed on all constructional materials reduce the number of cases in which the strength is found to be lower than that taken as a basis in the calculations; but on the other hand, there is no chance of benefiting by a greater strength. In the case of old metal, certain Railways always consider this defective; they base their arguments upon the fissility inherent in iron and after a certain age the metal is always suspect. However, apart from flagrant cases in which the metal is severely affected by corrosion due to faulty maintenance, it has never been clearly proved, as far as we know, that the strength and elastic strength of the metal of old bridges is in any way impaired. The minimum quality obtained at the time of construction can always be taken as a basis.

Evaluation of the stresses and deformations on the other hand is impaired by considerable errors. From the time of construction, near the rivet holes and in the assembly there are tensions exceeding the limit of elasticity, and consequently double or triple the stresses found by current calculations. The conditions under which the metal adapts itself and the stresses distribute themselves in a section and between sections are still insufficiently known. The rolling stresses already present in the sections used further complicate matters. A precise determination of the stresses and deformations due to a tendency in the parts to buckle or warp is still inaccurate; the compensating dynamic majoration applied to the stresses is often of an arbitrary character, etc. A calculation of the stresses and deformations at the moment when their importance is sufficient to affect the safety criteria requires much greater sagacity than the usual calculations imply.

A rational comparison of the safety offered by bridges will bring into the picture figures for the stresses of a much greater value than those usually considered, but doubtless they will make

it possible to retain a certain number of bridges which would be condemned by the present checks.

Under present conditions, in spite of the lack of precise details of the risk of putting a bridge out of service, the fact is that railway bridges as a whole prove satisfactory.

Apart from fissures in parts attributable to imperfections of construction, and corrosion, no accidents have been reported (welded parts coming apart), except for traffic during or due to the war when much heavier overloads had to be tolerated than those allowed by the normal regulations. The *Finnish Railways* report the fracture at its point of attachment of a cross piece of the central section of a 34 m. (111'6¾") bridge subjected to excessive transverse stresses during the oscillations set up by traffic.

The *Rumanian Railways* mention the collapse of military bridges used for traffic leading to stresses exceeding the limiting stresses by 50 %. The fracture of the joints on temporary bridges after damage by shock without any initial fissure being observed has also been noted. But no precise cases of failure in service of any important well built and well maintained structure have been reported.

It may be deduced from this that all railway bridges are sufficiently safe under present operating regulations. The risk of making them unsafe for traffic varies widely from one bridge to another, so that in many cases it would certainly be possible to increase the overload without lowering the safety factor to a degree corresponding to the lowest. Experience confirms the technical considerations on which the present regulations are based.

If the usual calculations are to be adhered to, a general increase in the admissible stress can only be considered with circumspection in those countries where the limiting stress is already a high fraction of the elastic limit; a more accurate determination of the dynamic majorations through actual experience would however make it possible to replace the stresses calculated in certain cases by lower values.

But if we are to go outside the framework of the usual checks, we might get closer to the idea of theoretical safety and that of effective safety. The criterion for withdrawal from service is not the exceeding of the limit of elasticity at a certain point, but the apparition of critical deformations. In the case of current types of bridges, these signs are easily recognisable, and the corresponding theoretical stresses can be calculated by the methods in current use. Taking the latter as a basis for the usual limiting stresses of works of the same type, the admissible overloads are determined more satisfactorily than with the present regulations. It would seem that interesting results from the financial point of view can be obtained in this way by keeping metal bridges in service without adversely affecting safety in any way.

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B. — Recovery and strengthening of metal bridges.

Bridges which have reached the limit of safety must be strengthened in order to be able to stand up to the overloads to which it is proposed to submit them under normal conditions. Two methods are generally adopted in this connection : replacement or strengthening. Replacement by a new bridge made of metal, reinforced concrete, or masonry presents no technical difficulties, except for the erection of very large bridges while the line is open to traffic. It is however an extreme solution which we hesitate to employ in the cases of bridges of a certain size until a thorough investigation has been made into more

economical solutions. The latter only are dealt with in the present report. We will consider in turn replacement by a recovered bridge, and strengthening on site.

Recovery of metal bridges.

Programmes for putting into service more powerful locomotives or modifications in the operation of lines leads to bridges which gave good service under other conditions being down graded. Such bridges are still sufficiently good for service on lines of lesser importance; if on such a line a bridge of the same dimensions has reached the limit of its strength it can be replaced by the former; the only expense involved is the cost of transport and putting into place. The saving in comparison with the erection of a new bridge even makes it possible to spend a little money on the replacement bridge, to adapt it still better to its new site, improve the strength of certain parts or replace others, without the expenditure being in any way comparable with that involved in erecting a new bridge.

However it is rare to find simultaneously two identical bridges needing replacement, one on a main line and the other on a secondary line, and even when it happens, considerations of financial expediency may involve postponing the double substitution. The operation is then burdened with repairs and by putting into store which materially reduces its value. For this reason most Railways only carry out replacements of this kind under exceptional circumstances.

Apart from the total recovery of a bridge, parts of bridges can be re-used in new bridges or in strengthening existing bridges, such as parts of the framework, complete main girders, parts of the bridge under the track. Here again the operation is only advantageous when removal and re-use are practically simultaneous; on the other hand the storing of parts unless it is known exactly where and when they can be re-used is in general very much less advantageous than it appears.

From the technical point of view, recovery gives rise to no serious difficulties apart from the transport of large sections. In the case of small bridges, there are numerous examples of recovery which has taken place with or without stocking. In the case of medium and large bridges, recovery nearly always only takes place occasionally; such circumstances as modifications of the layout of lines or their reconstruction at the end of hostilities and the general shortage of steel have caused it to be practiced on a larger scale in certain countries.

Various interesting cases have been reported by the Administrations; naturally we will not deal with the numerous instances of salvaging bridges destroyed during the war when salvaged sections have been used either temporarily or permanently by altering them and piecing them together to suit.

Small bridges.

The *Sfax to Gafsa Railway* in the case of 4 to 15 m. (13′1½″ to 49′2½″) bridges now makes it a standard practice to take up such bridges and re-use them either at the same site or another after they have been repaired and strengthened in the shops. The bridge after being replaced by a temporary bridge is transported to the shops on an open wagon, the necessary work done there, then reloaded and taken back to the site and put in place. These operations are carried out according to an exact programme and are considered to be financially beneficial.

Medium bridges.

The *Netherlands Railways* which had to deal with seventeen 28 m. (91′10$^{3}/_{8}$″) 2 span bridges, situated side by side

on the shunting roads of a busy station, made a special wagon which made it possible to replace an old bridge by a reinforced one very quickly. The former was taken to the shops, strengthened as required and then took the place of another bridge needing strengthening. The special wagon makes it possible to carry the new bridge above the old one, lift up the latter, conjointly with the new one, tipping the whole 180° and lowering the new bridge into place. Traffic is interrupted for less than 1¾ hour. The gear makes it very easy to lay bridges up to 21 m. (68′10¾″) long, and enables small bridges to be laid as the line advances.

Similar wagons have been built on various Railways for handling and putting into place 20 m. (95′1¾″) bridges or even longer girders so long as the latter do not exceed the limits for the weight to be balanced.

The *French Railways* have re-used a large series of bridges, since after they had restored the bridges destroyed during the war they found they still had a large stock of auxiliary bridges. Most of these were of the twin girder type, which is usually adopted on account of its small thickness; they had been calculated for the heaviest overloads, but with a working rate exceeding the limiting stresses of new bridges by 20 %. The re-use of these bridges enabled a large tonnage of metal to be saved. They are either cut down so as to bring them in line with the span allowed for bridges of this type; or else strengthened in the shops so that every part is as strong as a new bridge. The original arrangement has usually been retained, the bolts being replaced by rivets and suitable side members added. Sometimes only the girders have been re-used, fitted with new struts and a concrete platform to hold the ballast. A certain number of these bridges have also been re-used under narrow gauge tracks or under roads. The shortage of metal, the limited amount of stock on hand and the excellent condition of the bridges justified such use unreservedly.

The *French West African Railways* have remade the old Kayes-Niger line for 308 km. (201 miles) and replaced in turn the 25 m. (82′¼″) spans; the bridges weighing 36 tonnes (35.431 Engl. tons) were lifted by means of gantrys, put on lorries and taken to their new site; others of smaller span were taken apart and the girders alone taken to another section where they were used as deck bridge with buckled plates flooring and ballast or as embedded girders. Such re-use makes it easy to obtain plenty of spares, requiring little subsequent maintenance. The distance from the plant and the restrictions due to single line working made such re-use of particular value.

Larger bridges.

The *Polish Railways* report the re-use of an 88 m. (288′8⅝″) bridge for double track which had become insufficiently strong for the traffic. A new single track bridge was made and put in position, when the old bridge was removed and altered into a single track bridge to serve for the second set of lines, for which it was then amply strong enough. The Polish Railways have also used 97 m. (318′3″) girders from old bridges to double girders of the same span on similar bridges.

The *Swiss Federal Railways* mention the case of a three span bridge [26, 31 and 26 m. (85′3⅝″, 101′8½″ and 85′3⅝″)] which was taken up (after a new bridge had been built to take its place) in sections which could be dealt with by a crane, taken to another line, rebuilt and reinforced as necessary (new stringers, braking frames, strengthening the gussets of the struts) then substituted for the old bridge by shifting.

30 m. (98′5⅛″) girders, taken from bridges which have been replaced, have been salvaged and used to double the

girders on similar bridges retained in service. Salvaged girders have been re-used as main girders on bridges after being reinforced by increasing their height by cutting the web longitudinally and welding in a plate. At other times, the girders have merely been cut to the desired length and been made good in the shops. Girders have even been cut up so that the sole plates of the ribs could be re-used in reinforced concrete bridges. It was the shortage of metal that led to the last named solution being adopted.

The *Turkish State Railways* quote the case of a 52 m. (170′7¼″) bridge which was taken down, marked, and taken by wagon to the shops where its span was reduced by turning it into a two span bridge. The base plates and lattice-work adjoining the new supports were strengthened, as well as the horizontal stays. This work was done on account of the shortage of materials due to the general economic situation.

The *French Railways* have had occasion to re-use certain large bridges, either because certain lines have been given up on which the bridges were still in a good state of repair, or in order to save time and metal in rebuilding bridges destroyed during the war.

For example a trellis girder bridge of 27 m. (88′7″) span has been re-used for a shorter span, after being taken down into sections that could be carried by lorry (the line had been taken up), loaded onto wagons, taken to the shops where the central panels were suppressed. Bridges have been taken to the shops after being taken down, reinforced and taken to their new site; sometimes the original span was retained, sometimes they have been shortened and new ends made.

During the reconstruction work carried out during 1945 several 30 and 40 m. (98′5$^{1}/_{8}$″ and 131′2¾″) bridges parts of which were in a bad state of repair were broken down into their component parts (girders, struts, stringers) and picked up by means of cranes with shoring to prevent the pieces taken apart from slipping; the sections of girder loaded onto wagons and taken to the shops where they were altered, repaired and reinforced. The transport route was carefully planned in order to allow of the transport of as large sections as possible; for example sections 35 m. (114′10″) long have been carried over long distances. After the repairs were completed the bridge was taken to its new site and often put into position (or into a temporary position to enable it to be shifted into position), by means of cranes; if needs be, the assembly was carried out very fast, without scaffolding, one section being held by the crane. This method enabled bridges to be recovered and re-used very rapidly at a time when metal was in extremely short supply and it was difficult to find the labour for carrying out repairs in the country.

A very good example of re-using a bridge without taking it down is the transfer of the Neuf-Brisach bridge to the Chalampé bridge, 26 km. (16 miles) down the Rhine. The single track Neuf-Brisach bridge, of recent construction, had a span of 72 m. (236′2¾″) and weighed approximately 500 tons. It was desired to remove it to Chalampé to close a breach of similar size and the best way to do so seemed to be by barges. The course of the river however made it impossible for it to be taken on barges in a single piece, and the bridge had to be divided into two sections; a pier was built for the job. Scaffolding mounted on the barges carried the large section which after being taken to its site was turned towards the bank on a level with the rebuilt pier, by means of an up-stream and down-stream cutwater. When the second section arrived the two were assembled and the whole put into place. The means of transport consisted of two barges 65 m. (213′3$^{1}/_{8}$″) long with a 2 m. (6′6¾″) gap between

them, the weight of the gantry carrying the sections being divided between them. The operations at arrival and departure were effected within a few yards by means of a winch. A 4 000 H.P. tug was used for traction purposes, which ascended the Rhine at a speed of 5 km. (3 miles)/h.

Thus in periods when it is necessary to replace a large number of bridges very rapidly, the re-use of structures has possibilities which must not be overlooked, especially as regards the time saved and the economy obtained. In normal times, it is rare to find bridges of approximately the same dimensions which have to be replaced at one and the same time, and even if such cases occur, the bridge to be re-used usually has to be taken to the shops for alteration, which makes the job expensive. Moreover, bridges which can be re-used are not, as is the case after a war, bridges in a good general state of repair, damaged at one or two points; they are a little or much too weak as a whole in their present site, and at the new site will not have a great deal of reserve strength; there are defects in them (rivets too widely spaced, lack of plates, worn fastenings) which cannot be made good at a reasonable cost. In the case of bridges of some size, particular circumstances which would make such re-use of interest are unlikely to occur. In the case of small bridges, conditions favouring re-use are more likely to be met with, and certain Railways systematically investigate their programmes for the renewal of bridges with this end in view. But the stocking of bridges in view of their eventual re-use and, still more so, the stocking of bridge parts which have been taken apart, generally involves expenses and restrictions which can only be justified at periods when the supply of new material is practically impossible.

To sum up, the re-use of bridges in order to be profitable involves special circumstances, and a very careful study of the programme of reutilisation; it can however have considerable advantages under such conditions, especially as far as the saving of time is concerned.

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Reconstruction and strengthening of metal bridges.

The method most frequently employed to increase the strength of a bridge to the desired extent at the lowest possible cost is to increase the section of the weak parts or replace them by stronger parts. In the case of fairly new bridges, a little additional metal often suffices; but in the case of older bridges, it is often difficult to add sufficient new metal; moreover they may have defects due to rusting or faulty construction; taking the parts apart may cause cracks, or deformations of the adjoining parts; the reinforced structure, even if it is theoretically satisfactory, has in reality not the full strength counted upon. The *Turkish State Railways*, report, with reason, that it is often preferable, especially as far as the supports are concerned, to allow for a theoretical stress exceeding to some extent the limiting stress rather than carry out reinforcement when so doing inevitably causes damage to adjoining parts. The difficulties in the way of carrying out the work are still greater seeing that it usually has to be done without interrupting the traffic over the bridge. The best technical results are obtained when traffic can be diverted while the work is being done or use made of an auxiliary bridge. It is even better when the bridge can be taken to the shops. But this way of carrying out the work usually involves heavy expenses which seriously affect the total cost of the reinforcement.

When the sections have to be strengthened to such an extent that it is impossible to count upon satisfactory

technical execution of the work, the possibilities of the second method of reinforcement should be considered; this consists, instead of labouriously adding small sections of steel to all the parts, of deliberately removing from the old bridge a large part of the stresses it has to support by means of a new framework or additional parts which will alter the distribution of the load. The great advantage of this method is that the old bridge is not disturbed in any way. Nor is the traffic much affected. We give below some examples of the use of these two methods.

Reinforcement on site by rivetting.

The question of strengthening railway bridges at the present time only concerns rivetted structures. Consequently the reinforcement is usually made by rivetting. This method of repair is well known : the only special feature is that traffic must not be interrupted while the work is being carried out. In order to avoid having to remove essential parts, the fitting of the reinforcements may be made somewhat more complicated. Parts which affect the strength have to be removed during the intervals when there is no traffic or by protecting the parts to be replaced from the overloads (provisional decking, provisional parts to replace or double the others); the trains are allowed to run over assemblies with a smaller number of assembly bolts or even with pins alone. The strength of the bridge is reduced while the work is being carried out and it is often necessary to impose certain load and speed restrictions. Reinforcements of all kinds and extent have been carried out in this way by most Railways, for example :

adding additional flange plates of flats and rolled sections to the flanges of the girders and trellis bars;

adding web plates and gussets, renewing flanges, rolled sections, corner plates, introducing bushes, and using braces, etc.

The technical results obtained depend a great deal on the quality of the unrivetting and rivetting. It is difficult to get the former operation well done at a satisfactory price; often the old holes have not been sufficiently reamed out, the parts have worked and the shank of the rivet is uneven which makes it difficult to get it out when the head has been removed. If brute strength is used the result often is that cracking will occur round the holes which will mean that the part will have to be scrapped if the damaged metal cannot be completely reamed out; the drilling of a pilot hole before knocking out the rivet is more often necessary than one would think. The old rivet holes are often so oval in shape that it is impossible to ream them out satisfactorily; so that it is often necessary to scrap more parts than was expected. Consequently prudent planners will use all their ingenuity to limit the number of rivets that have to be removed on important parts as much as possible.

Distribution of the load between the old and new parts.

The stresses which occur after reinforcement has taken place are estimated by taking into account the deformation of the parts under load and the coefficients of elasticity of the material forming the new section. The distribution of the stresses due to the dead load depends upon the way the work is done. In general, no special precautions are taken and the new metal has no effect on the strength except in so far as the loads occurring after it has been put in place are concerned. The old metal which has to carry in addition to its share of the overload the old and new deadweight, often reaches the limit of its strength, whereas the metal which has been added only supports a relatively moderate load; the new metal is incompletely utilised.

To improve this state of affairs it is necessary to free the old metal from some of the load when the new metal is put into place, and certain attempts have been made to do this. In certain very rare cases it has been possible to place provisional piers under large bridges by means of which the bridge could be freed from certain stresses carefully calculated beforehand; the reinforcement was then made to the bridge which in this way had been partly freed from the deadweight. Similar results are obtainable in the case of bridges with multiple girders by setting down the girder to be reinforced by means of trimmers bearing on the other girders. But such work, if it is to be properly carried out, requires very long intervals, as well as careful workmanship, which makes it expensive. No recent cases have been reported to us.

Similar difficulties occur when replacing the bars of trellis girders. If no special precautions are taken the girder has no proper tension under the dead weight, and after successive substitutions, the bridge is markedly out of shape. Drilling is sometimes done to a gauge such that the length of the beam between the rivet holes differs by a permissible amount from the distance between holes on the corresponding gussets; on assembly the holes are made to coincide, either simply by broaching or by heating the beam just sufficiently to enable the pins to be put through, so that the new beam is under stress. Another method is to use an auxiliary diagonal in line with the beam to be replaced connected to the ribs by provisional lateral gussets; a system of screws and bolts makes it possible to stress this diagonal to the desired extent. When the beam has been replaced, removal of the diagonal transfers nearly all the stress to the beam itself.

In the same way in order to make the new metal share in carrying the dead weight, steps were taken during certain repairs to bridges damaged during the war. It was, for example, the central part of an intermediate span of a girder bridge. After this part had been rebuilt, partly jutting out and partly on scaffolding, the stresses on the piles were very different from those corresponding to the action of the dead weight on the bridge as a whole. But when joined end to end by making suitable adjustments to the level of the bridge on the surrounding supports and restoring it to the old level, it was possible to restore the stresses allowed for in the calculations.

Generally, the difficulty of putting new metal under the appropriate stresses for the dead weight involving as it does delicate and often illusionary manœuvres, makes it seem preferable to increase the weight of the reinforcement slightly, and obtain thereby a moderate working value for this metal. Thus the use of high tensile steel, the properties of which would not be fully utilised under such conditions, is not a common practice in the reinforcement of sections. Mention may be made as an exceptional case of the use of high tensile steel for the replacement of the beams of a 30 m. ($95'5^1/_8''$) bridge on the *French Railways* by diagonals of the same section in steel of 54 quality. The arrangement of the bridge in which the beams stressed in tension cross those in compression made it difficult to increase the section, so it was decided to accept a higher working stress and consequently use this steel for the replacement.

Reinforcement of sections by welding.

The difficulty of adding metal to rivetted sections has made the use of welding a matter of interest for a long time, and the technical improvements made in the latter during the last twenty years have multiplied the possibility of its application. Its use is of particular

value when it makes it possible to avoid taking out essential rivets and it has enabled much remarkable work to be done. Certain Railways consider this to be the only practical method, since it involves much less upset to the working than rivetting. Others on the contrary will not agree to it as a normal method of reinforcement, owing to the difficulty of ascertaining if the welds have been correctly made.

The objection is less serious than it seems if it is intended to call in question the irregularity of the quality of the metal deposited, which depends first of all on the technical skill and conscientiousness of the workman. Experience shows that precautions taken in choosing welders, and careful supervision during the work are sufficient to eliminate dangerous defects. The testing of welds and the X-ray examinations sometimes made do not reveal many defects which are not otherwise visible.

The origin of the troubles and accidents which have occurred with welded constructions are due rather to a defective adaptation of the electrodes to the metal, insufficiently carefully planned work or badly designed work, rather than to badly made welds. All these points can be carefully checked.

Reinforcements carried out after careful preliminary tests have behaved perfectly to date, the rare cracks which have appeared being visible straight away or as soon as traffic was resumed. It may also be pointed out that the break down of a weld on a reinforced part, only affects that section and is much less serious in its results than the breaking of a part in a new welded bridge.

The incidents reported by the Railways concern new parts, and temporary bridges, not parts reinforced on site. The general cause seems to be the design of fastening, pre-existing internal stresses or stresses due to a defective method of welding; consequently the consequences are visible in most cases immediately the weld has been made or soon after the part has been put in place. It would seem therefore that objections on the ground of the impossibility of a certain and sure control on the quality of the weld can be overuled; careful supervision during the work is sufficient to prevent any serious mistakes by the workman. On the other hand properly made welds may give bad results owing to the stresses to which they give rise in the original metal. Fortunately such stresses nearly always become manifest immediately so that the man in charge of the job can alter the way the welding is done before the work continues; it would appear that the danger caused by stresses in the metal diminish as a rule as time goes on.

Those who are fully aware of the advantages of welding : less scaffolding, great reduction of the weight of metal required for strengthening, possibility of carrying out jobs impossible with rivetting, may be reminded of the difficulties in the way of making perfect welds.

The first concerns the basic metal; if it is too carburized or corroded, the risk of a poor weld is increased. If it is a case of old iron, which is flaky in structure and in which the mutual adhesion of the lamina is very weak, the use of welding without careful precautions will give rise to a weak weld which easily causes continuous or localised cracks. In the case of new metal, the use of as mild a steel as possible together with electrodes giving the greatest elongation possible will give better results than metal and electrodes with a high resistance which is often superfluous.

The second difficulty concerns the arrangement of the welds; recommendations on this subject are mostly negative: avoid too large welds, discontinuous welds, accumulations of welds, crossing of deposits, dissymetries; the arrangements which look the most satisfactory are not always the best.

The third point concerns making the welds and their behaviour; here again each failure leads to the formulation of another rule, which is often found to be contrary to an earlier one : welds in difficult positions, changes in weather may prevent the work being carried out in the order specified to avoid shrinkage stresses.

To sum up, the making of perfect welds depends equally on regulations based on reason, skill, design and execution which are all part of the art of welding, and also on the possibility of applying all the recognised rules without making the cost of the welded reinforcement prohibitive.

After the work has been done, it is very hard to check it on site; observation of the welds under X-ray has not been extensively carried out, and has often been found difficult of interpretation, especially when the basic metal is of mediocre homogenity; moreover it does not pretend to do more than give an indication of the intrinsic quality of the weld, and cannot give any indication of the stresses set up in the neighbouring metal, stresses which appear to be the root cause of defective welds on bridges.

The conception of welded reinforcements is very similar to rivetted reinforcements. For example supplementary plates are used and assembled by means of lateral welds. One difficulty then is the presence of the old rivets which prevent the new plates coming into contact; various ways of overcoming this have been used, the most usual practice being to place the strengthening steel between the rows of rivets, the welding sometimes being broken in line with the heads. They have also been covered by a plate first of all, drilled to take the heads, or arranged to fill in the spaces between the heads, the gaps being filled in with welds or not; additional plates then cover in the whole surface. Sometimes new arrangements have been adopted, very high flats welded along the edge, sections U V T I welded, leaving a gap between the old metal and the strengthening pieces, addition of various sections in excentric positions completely covering the initial section; there are objections to many of these realisations, but nevertheless they have stood up well and have cost much less than equivalent work carried out by rivetting.

The reinforcement of the bars of trellis girders has also been carried out, but it is often necessary to abandon the most simple arrangements to obtain on thin parts sufficient adhesion of the reinforcement metal to give the desired theoretical strength, without too great excentricity and which can be correctly made. Moreover, welding the fastenings of new bars has to be carefully studied, owing to the stresses developed in the base metal. It has sometimes been thought prudent to weld one end only of a free bar, the other end being rivetted, although excellent results have been obtained under difficult conditions; the *Tunisian Railways* have reinforced bars of 42 kgr. (92 lbs.) steel damaged during the war with 72 kgr. (159 lbs.) rails fastened by welding only.

Apart from the reinforcement of sections, the use of welding is of great service in repairing corroded or weakened parts, thanks to the saving in labour compared with removing rivets.

The Administrations consulted did not send us any detailed examples of reinforcements carried out by welding; doubtless the conception of such reinforcements did not give rise to any general observations. In order to stress the importance of certain reinforcements carried out by welding, we will mention the case of the Austerlitz viaduct of the *Paris Metropolitan Railway* and the restoration of the Oissel bridge on the *French Railways*.

The Austerlitz viaduct, built in steel

in 1901 to take 185 tonne trains is an arch bridge with three articulations of 140 m. (459′3¾″) span with intermediate floor; it had to be strengthened to carry trains weighing 420 tonnes, and to allow 700 trains a day to cross it. Reinforcement by welding seemed the only possible solution; it was done by adding sections of up to 70 × 130 to the flanges of the arches between the rows of rivets, increasing the section of the trellises by 150 % and that of the supports by 66 %, that of the stringers by 65 % and that of the stays by 25 %. The total weight of metal used for reinforcement was 275 tonnes, more than ⅓rd of the original weight of the bridge, involving making 1 500 000 cm³ (91 536 cubic inches) of welds. By this means the method to be followed to overcome the deformations and prevent internal stresses being set up was decided upon and the effects of the residual stresses on the final strength defined; the use of a specially mild steel for the reinforcements seemed to be indicated, and Martin steel with 0.1 % carbon and 0.4 % manganese with a breaking limit of 38 kgr./mm² (24.13 tons per sq. inch) and elongation of 25 % was chosen. Very careful precautions were taken while the work was being carried out. The plates on the arch flanges were ground to make sure they fitted correctly, and the reinforcement bars made to gauge. Trials carried out on full size reinforced plates made it possible to check the behaviour of the welds by bending through 90° an assembly 20 cm. (7⅞″) thick (5 plates of 12 and flat of 130 in height) : all the welders had to undergo periodical examinations, the filets were tested by means of the Smückler apparatus. The work, which took nearly two years, was done entirely on scaffolding, so that the trains were able to run freely all the time.

The Oissel bridge, an old iron bridge on the Paris-Le Havre line, with three spans of 66 m. (216′6½″), 66 m. and 52 m. (170′7¼″) respectively, was bombarded on several occasions in 1944; it was cut in several places and nearly every part was damaged. A temporary structure on piers was erected so that trains could cross the bridge, but it was considered necessary to replace the whole bridge which meant using a large quantity of metal. To repair the old parts by rivetting entailed using almost as much metal as replacing the bridge. Consequently it was decided to conserve all the usable parts of the old bridge by making new welded joints. To prevent internal shrinkage stresses, the additional parts were assembled by welding with free play on one side only; on the other side ordinary rivetted joints were made. Completed sections of flanges and bars were pieced together in this way (the joints of the web and flanges were made out of line). In spite of the experience of the contractors in welding iron, the first results were not entirely satisfactory; special investigations had to be made to find out the best way of working, the current intensity to be used, etc.; the bend test pieces which cracked at first when bent through an angle of 10° gave bends of 80° after the method had been perfected. When the work was carried out under very strict supervision, no trouble was experienced; tests made of some of the runs of welding showed that the joints had been perfectly filled up; two flaws which appeared during the work of repairing the webs of damaged stringers were made good and have not reappeared. The tonnage of the new parts added by welding was 410 tonnes, and that of the parts repaired on site 85 tonnes; the length of the welds amounted to 3 300 m. (10 826′9″).

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The use of welding for reinforcing metal bridges is of great value at the present time and from the point of view of the technical results obtained compares advantageously with rivetting;

structures reinforced in this way stand up well in service, even when the carrying out of the work has presented difficulties. The chief advantages resulting from the use of welding are the facilities it gives for maintaining the traffic (reduction of taking apart and scaffolding). The technique to be used requires careful investigation, and even a fairly long experimental stage in which considerable difficulties may be encountered when beginning each job, especially when it is question of welding old iron or high tensile steel : very careful supervision to see that the technique decided upon is carefully followed and proper results obtained is essential, but this seems to be all that is needed to prevent failures. The precautions that have to be taken will affect the cost to a considerable extent, and it appears fitting to retain only those the value of which is well proved.

Reinforcement of bridge sections by reinforced concrete.

Strengthening sections of metal bridges may be carried out by using concrete or reinforced concrete. It may be a simple casing in some cases with the object of preventing oxydization and facilitating maintenance, whereas in others it has become such an important factor that the strength of the old structure is now only ancillary. Encasings have been made at various times by several Railways, either of the whole bridge or of certain parts such as the decking under the lines, the ribs of corroded beams, etc., with the idea of protecting the metal once and for all from oxydization and obtaining a better distribution of localised loads. Many such jobs have been carried out without any special precautions being taken against cracking, and this has resulted in superficial deterioration and seepage, so that the results cannot be considered entirely satisfactory; they call for reservations concerning the certainty that the metal is well protected near the cracks and there is the difficulty of making proper repairs when these become necessary. However structures treated in this way stand up very well in service and would seem to have a normal span of life. Such results incline us to be optimistic as to the behaviour of the casings which are now being made while the traffic is interrupted and with proper precautions to assure the adhesion of the concrete and bind it by a suitable arrangement of steel reinforcements.

The *Swedish Railways* have completely encased some old trellis girder bridges, either retaining the triangular beams, or turning them into full beams.

Important reinforcements have been made to large bridges with cast or iron arches, especially in Algeria and France. The bridges in question consist of a certain number of arches some 50 m. (164′½″) in span, with spandrels supporting the decking and its ballast. The reinforcement has consisted in encasing the upper and lower parts in a transverse reinforced concrete plate reaching either over the whole length of the arch or only towards the beginnings. The adhesion of the concrete is assured by cleaning the metal by sand blast and welding various elements to facilitate the anchoring of the concrete. The superstructure has either been retained or replaced by a reinforced concrete plate under the track. The results have always been satisfactory.

The encasing of bridge sections is therefore sometimes a valuable way of strengthening them from the double point of view of increasing the strength of the structure and reducing the ultimate cost of maintenance. The carrying out of the work should be accompanied with careful precautions concerning the quality of the concrete and the way it is used, so as to reduce the likelihood of cracks which whilst not affecting the strength of the bridge as long as they

remain filamentary, nevertheless give rise to criticisms and in the end to anxiety.

When the parts to be encased are not very simple in form which makes the work easy to carry out, or when they cannot be shielded from the action of moving loads, the cost and quality of the work are largely affected.

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Reinforcement of metal bridges by altering the way the structure functions.

In reinforcing bridges by increasing the section of the parts, one is soon brought up by the difficulty of fastening the new section needed to the old metal : the limit of the possibility of such reinforcement as will leave the theoretical functioning of the structure unchanged is reached. But if this theoretical function is modified by the introduction of new parts, it is often possible to lower to a great extent the working stress in the old metal.

For a long time use has been made of the method consisting of reducing the span by building an intermediate pier; the metal reinforcement merely consists of providing a suitable bearing and strengthening the adjoining beams. The traffic is very little affected and the technical results are very certain. The cost varies naturally within wide limits according to the height of the bridge and the ease with which the new pier can be made. There are examples of this method being used with spans of 62 m. (203′5″), 46 m. (150′11″) high. Nowadays the use of reinforced concrete is generally the cheapest for new piers.

The *Swedish Railways* have applied this method to various old viaducts : according to the height of the bridge either intermediate piers are made in reinforced concrete, or reinforced concrete arches provided, supporting the original span by means of small piers. The old framework was either conserved intact or encased, and new framework only put under load after the concrete had hardened.

Another method, widely used, is to relieve the main girders by adding arches either above or under. These arches can be made to the size shown necessary by calculation, and the load from which it is desired to free the old framework transferred to them by means of uprights and supports. The thrust is absorbed by the ribs to which the arches are attached. The new framework is relatively cheap and easily assembled, so that there is little interruption to the traffic. Before it is rivetted, the stresses transmitted to each support can be regulated if there is no overload to distribute the stresses better; this regulating is done before rivetting, by means of screw-jacks, regulated springs, etc. Since the well known application of this method by the Swiss Railways on the St. Gothard line, this process has been used many times. Recent examples are mentioned by the *Swiss Federal Railways* [single spans of 50 m. (164′½″) and bridges with two 50 m. spans] and the *French Railways* (4 continuous spans of 17 and 23 m. = 55′9¼″ and 75′5¼″).

The *Swedish Railways* have used the opposite method to reinforce a large bridge with three 61 m. (200′1⅝″) span; the straight girders with parabolic upper ribs were transformed into girders with subtended arc by adding large trellis girders below the lower ribs, suppressing the diagonals and adding supports.

Another process, which is often found convenient, for reinforcing the main girders of metal bridges is to lay new girders alongside them, which are linked up with them and bend with them and aid them in supporting the overloads. The value of this solution lies in the

ease with which the work can be carried out without disturbing the traffic. The new girders are often added laterally; in the case of bridges with an upper track, a third girder is sometimes put between the two existing girders. The *Greek Railways* have doubled the main bridge girders, 20 to 30 m. (65′7³/₈″ to 98′5¹/₈″) long with upper parabolic ribbing. The *Polish Railways* quote an example of five 97 m. (318′3″) spans, of a combined rail and road bridge, where a third girder of the same size was added in the middle. By this means the bridge was strengthened sufficiently to carry a second railway track in place of the road.

The idea of modifying the function of a metal bridge by means of additional parts can be extended to the reinforcement of isolated parts; uprights or diagonals have been added to strengthen trellis work, new stringers have been put beside the existing ones; intermediate struts have been fitted to relieve the struts and stringers, parts of the bridge, even the main girders have been supported by struts reducing the span, subtended by tie-rods. All such reinforcements are effective; they increase the strength much more certainly than increasing the section does; they can be carried out without any difficulty being experienced for the traffic. The only thing against them is the æstethical aspect; bridges reinforced in this way are often spoiled in appearance owing to amount of the additions and the confusion of their line which results therefrom. There is an interesting possibility which as far as we know has not been used to any extent so far, and that is the use of high tensile steel for the supplementary framework; it is possible to let this metal work at a high rate since it is not in forced contact with the stresses of the old metal, and the greater flexibility which results does not generally present any drawbacks.

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C. — Choice of the method of restoring bridges which have reached their safety limit.

The methods which we have just reviewed nearly always make it possible to strengthen a bridge sufficiently to take new overloads; however they are less frequently used than replacement of the bridge. This is because technical results, the cost of the work, and the time it takes to complete all affect the choice of the work to be done.

From the technical point of view, reinforcement sometimes calls for reservations. When the bridge is an old one, of defective design, with the fastenings weakened and the parts corroded, consolidation will not prove satisfactory and lasting. Even in the case of bridges in a normal state of repair, extensive reinforcement involves a risk of loosening certain supports and damaging certain parts, especially with a metal like iron which cracks easily; the increased strength proves to be less than that estimated. This is particularly to be feared when it is question of a bridge which has already been reinforced some twenty of thirty years behorehand; most technical experts consider that a second reinforcement is not advisable. Certain Railways are very conscious of these considerations and consider that bridges that are more than 60 years old should not be reinforced. This would appear to be too arbitrary : a judicious use of welding extends the possibility of reinforcement without removing the rivets and consequently the previous objections lose much of their force, if it is possible to make the reinforcement not by increasing the sections but by adding new framework; the use of reinforced concrete, when circumstances are propitious, also makes it possible to obtain reinforcements to cover every need.

In the case of old structures only reinforcements of this kind should, in general, be compared with replacements.

In the case of more recent bridges, where only certain parts are lacking in strength, the reinforcement of sections or the addition of supplementary parts, either by welding, or by rivetting, gives satisfactory results.

Complete replacement gives, in principle, the best results. When all the parts are sound and assembled according to the best technique known, they will last much longer than those of a reinforced bridge. The best combinations can be adopted without difficulty to facilitate maintenance, enlarge the structure gauge, modify the type of bridge, the better to meet operating requirements.

There are cases, however, where circumstances dictate the solution to be adopted. On lines with heavy traffic, metropolitan lines, lines where no traffic diversion is possible, the need for running the services without interruption will mean of necessity that the bridge must be either replaced if this can be done in an interval between trains, or strengthened if putting the new bridge into place during the time available is almost impossible.

A comparison of the cost will take into account the cost of new metal at the site. In places distant from the foundries, the cost varies a lot according to the situation of the bridge and the tonnage involved, especially in the case of reinforcements where the diversion of labour is of relatively greater importance. It is rare for the metal used for reinforcement to cost less than double the price of the same weight of metal in a new structure; consequently many reinforcements that are technically possible are of little interest from the financial point of view.

In the cost of the new metal at site must obviously be included the scaffolding and service-bridges, if needs be the taking down, removal and scrap value of the framework or other parts removed.

The work of reinforcement is often carefully planned in order to avoid any interruption to the traffic, but it frequently leads to speed restrictions and restrictions of weight which increase operating costs. Replacement causes trouble for less time, but if it involves a diversion of traffic or the making of a temporary bridge, the cost involved is against it. When the time taken to complete the work differs a great deal, any comparison made must take into account the savings which the use of new locomotives at an earlier date will produce.

Side by side with the direct and immediate costs, an estimate must also be made of subsequent costs : a new bridge will involve appreciably lower maintenance costs and it will last longer.

The question of the time taken in normal times only comes into the picture in so far as it affects the financial balance sheet. Moreover the amount of work involved in the reconditioning of bridges is of little account compared with the resources of the metallurgical industry and the engineering industry, and the time taken to make a replacement or reinforcement can be estimated with great accuracy : small reinforcements can be made with great rapidity, but large ones take almost as long as replacements.

In times of war when there has been a widespread and generalised destruction of bridges, however, more general considerations come into the picture, and the main concern is to restore the lines to traffic with less regard to expense and the technical value of the work done. The choice of solutions depends almost exclusively on the time it will take to do the work, and restoration, whenever possible, will be the quickest.

The above considerations may be summed up in formulæ which make a comparison between the cost of a reinforcement and a replacement. Such formulæ as those reported by the *Netherlands Railways* and the *Swiss Federal*

Railways, even if it is difficult to put them into practice and the considerations on which they are based seem somewhat over simplified, are of value in order to fix our ideas :

Let P_N be the total immediate cost of erecting a new bridge which will last n years with an annual maintenance E_N.

Let P_R be the total immediate cost of a recovered or reinforced bridge which will last r years with an annual maintenance E_R.

The two bridges over a period of r years will allow the same traffic to be worked, and at the end of r years, the former will be usable for $n - r$ years.

The use of the bridge during n years for a rate of interest t will cost :

New bridge :

$$P_N + E_R \times \frac{(1+t)^r - 1}{t\,(1+t)^r} - P_N \frac{n-r}{n} \frac{1}{(1+t)^r};$$

Restored bridge :

$$P_R + E_R \frac{(1+t)^r - 1}{t\,(1+t)^r}$$

Replacement is better if

$$P_R > P_N \left[1 - \frac{1}{(1+t)^r} \frac{n-r}{n} \right] - (E_R - E_N) \frac{(1+t)^r - 1}{t\,(1+t)^r}$$

Making $r = 25$, $n = 50$, $t = 0.06$,

$$E_R - E_N = \frac{5}{1000} P_N \qquad P_R > 0.82\ P_N$$

The result will differ appreciably if, as often happens, no account is taken of the interest. We then have :

$$P_R > P_N \frac{r}{n} - (E_R - E_N)\, r$$

i. e. if $r = 25$, $n = 50$, $E_R - E_N = \frac{5\ P_N}{1000}$

$P_R > 0.37\ P_N$

The economic limit between replacement and reinforcement differs widely according to whether money is or is not easy; this, quite apart from the geographical situation of the Railways, the nature of their traffic and their opinion as to the conservation of the metal of old bridges, explains why there are such differences in their replies concerning the choice to be made. The *Tunisian Railways* and the *Gafsa Railways* are of the opinion that in practice reinforcement is more economical than replacement, the *Greek Railways* consider that reinforcement should not be considered when it costs more than 60 % of the cost of replacement, the *Spanish Railways* consider that reinforcement should not be considered when it costs half as much as replacement, the *Rumanian Railways* reduce this proportion to 40 %. On the other hand the *Swiss Federal Railways* have come to the conclusion that reinforcement is only of interest when it is very limited in extent and makes it possible to lengthen the life of the structure very appreciably, while the *Austrian, Belgian* and *Finnish Railways* consider it is nearly always better to replace bridges.

Replacement is better when any reinforcement involves a great tonnage of metal (25 to 30 % of the weight of a new bridge) the use of which will involve expenditure exceeding the limiting value corresponding to that at which it is financially a matter of indifference. The great diversity of opinions leads us to believe that each case should be considered on its own merits, and that appreciable savings can often be made by making a rational comparison of the costs involved in the various solutions that are technically possible.

These remarks are of value more particularly in normal times. They have to be reviewed when the cost of materials and labour vary a great deal or when the shortage of metal makes it impossible to use the tonnage needed.

Increased costs lead to replacements being made to the greatest extent possible financially. If, at the end of 25 years, prices have increased in the proportion of 1 to k, the limiting cost of replacement in the preceding formulæ becomes :

$$P_R \geqslant P_N \left[1 - k \frac{1}{(1+t)^r} \frac{n-r}{n} \right] - \frac{k+1}{2} \frac{(1+t)^r - 1}{t(1+t)^r} (E_R - E_N)$$

if $k = 1$, $P_R = 0.82\ P_N$

if $k = 3$, $P_R = 0.52\ P_N$

if $k = 6$, $P_R = 0.08\ P_N$

When there is a definite programme of bridges to be put into order, all the available financial resources will be utilised if only those bridges corresponding to the lowest values of $\frac{P_R}{P_N}$ are reinforced and the others replaced.

A shortage of available steel for repairing bridges on the other hand means that reinforcement will be the policy pursued rather than replacement. The programme can only be carried out if the weight of metal involved in the reinforcement is less than the available tonnage. The surplus is used to replace those bridges with the highest $\frac{P_R}{P_N}$ rather than strengthen them.

At the present time, in many countries, we come across two exceptional circumstances mentioned above : a shortage of material and of labour, and a risk of a rise in prices. The shortage of steel is an urgent matter and tends to favour reinforcement; however, if it is thought that this state of affairs is only temporary, reinforcements that are too costly will not be undertaken and attempts will be made to achieve the desired results by temporary measures in the meantime. In such cases, the Railways practice speed restrictions, prohibitions of unduly heavy engines, restrictions on the tonnage of trains, prohibition of trains meeting on double track bridges.

If needs be, they make provisional supplementary supports to strengthen weak bridges; precautions then have to be taken concerning the adjustment of these supports and conservation of their level. The *French West African Railways* have generalised in this way the provision of intermediate supports on the bridges over a 100 km. (62 miles) section of the Kayes-Niger line, to enable the loads to be increased until such time as the work of renewal can be undertaken, while on the other sections important restrictions have been retained in force.

Economic considerations which, in normal times, would make possible a rational choice between reinforcement and replacement have thus to give way to other imperative considerations; recovery and reinforcement are voluntarily applied on a wider scale than under normal circumstances.

* * *

SUMMARY.

The reinforcement and replacement of metal bridges are generally necessitated by the increasing weight of the overload.

The average tonnage of steel needed can be estimated as an annual amount of 3 ‰ of the weight of the rails on the main lines for replacements and 1 ‰ for reinforcements. The decision which puts a bridge into the « insufficient strength » class results from a strict application of the safety regulations based on the comparison between the calculated stresses and a limiting stress fixed according to the metal. The substitution of measured stresses for calculated stresses, the definition of the limiting stress of the material from tests

carried out on the metal of the bridge in question, a more exact evaluation of the dynamic effects and the allowable deformations may in certain cases, in the case of bridges in a perfect state of repair, justify an increase in the limiting loads so far allowed.

* * *

The restoration of a bridge may be carried out by replacing it or by reinforcing it. The replacement of a bridge by another from a different part of the system is of undeniable value when circumstances permit, in view of the saving in metal thereby obtained. The recovery of small bridges is practised at the present time by some Railways; the reconstruction of war damaged structures has provided occasions for applying this method profitably to average and large bridges. The taking down of bridge elements in view of their possible re-use is not generally to be recommended.

The reinforcement of bridges is achieved by strengthening individual parts or by altering the structure. Reinforcement of the sections by rivetting is the method most widely used, whenever additional parts can be added without necessitating removing the rivets from important fastenings. Reinforcement by welding, the technique of which is less well known, has certain advantages. Very large bridges have been reinforced by this method and have stood up well in service. Reinforcements making use of reinforced concrete have also given good results and given rise in certain cases to interesting solutions. The alteration of bridges by adding new elements, introducing new supports, etc., is to be recommended in particular for strengthening the main girders, since it makes it possible to do so without damaging the old structure.

* * *

A choice of the method of reinforcement must be based on the technical results made possible, the expense involved and the time taken to do the work.

The financial balance sheet of the different solutions can be drawn up fairly accurately. Replacement by a new bridge is more advantageous than replacement by a recovered or reinforced bridge when the immediate cost of the latter solution exceeds a definite fraction of the former. This amount varies with economic circumstances; it may exceed 60 % in stable times and fall to a very low value in times when prices are high. For example a reinforcement necessitating the use of additional metal exceeding 20 or 30 % of the weight of a new bridge, is rarely financially interesting. But such considerations are largely overridden under post-war conditions; the general shortage of materials and labour means that recovery and reinforcement will be carried out more frequently than in normal times.

SUMMARY OF REPLIES RECEIVED FROM THE ADMINISTRATIONS

Question I. — c) Recovery and strengthening of metal bridges that have reached the theoritical limit of safety.

The questionnaire only applies to metal railway bridges, i.e. bridges carrying railway track over roads, rivers, other railway lines, etc.

SECTION I.

QUESTION 1. — *Give approximately the total number of metal bridges on your system and the total tonnage of metal involved. If possible, give the figures for the small bridges (of less than 10 m. [32'9¾"] span for example) and for the larger ones separately.*

QUESTION 2. — *In the near future, how many bridges should be modified, on the average, every year, and what tonnage is involved? What are the most frequent causes leading you to modify a metal bridge? On the average what proportion of new metal is allocated :*

a) *to complete replacements,*

b) *to reinforcements carried out on site,*

c) *and reinforcements made in the shops or on a working site of bridges taken out of service for this purpose?*

QUESTION 3. — *What are, in general, the reasons governing your choice of* a), b) *or* c)*?*

Administration.	Question No.		
	1	2	3
Austria	10 000, i.e. 140 000 t.	6 000 to 10 000 t.	Replacement, as the metal is too old for satisfactory reinforcement.
Belgium & Colony. Belgian Nat. Rys.	...	Most of the bridges are of recent construction.	...
Belgian Light Rys.	> 12 m. 85, i.e. 2 550 t.	...	...

ADMINISTRATION.	QUESTION No. 1	2	3
Matadi to Leopoldville . . .	3 400 t.	...	...
Spain	5 009, i.e. 245 000 t.	Varies according to economic resources. Replaced by reinforced concrete bridges in the case of small bridges.	Replacement, as reinforcement is expensive; it cannot be limited to a small addition of metal and there is always some very old metal in these bridges.
Finland	< 10 m. 620 / > 10 m. 330 } 48 000 t.	15 to 20, i.e. 500 to 1 000 t. Increased loads.	Replacement, as reinforcement is expensive and inconvenient.
France & Colonies.			
S. N. C. F. . . .	< 10 m. 13 500 / > 10 m. 3 500 } 650 000 t.	300, i.e. 4 500 t. Increased loads; Damage or defects; Modification of the line.	Technical and economic balance sheet.
Paris Metro. . .	< 10 m. 80 800 t. / > 10 m. 290 31 200 t.	No modifications in view.	...
Algerian Rys. . .	< 10 m. 980 3 420 t. / > 10 m. 460 30 000 t.	Increased loads.	Cost and availability of metal.
Gafsa Rys. . . .	< 10 m. 519 870 t. / > 10 m. 84 1 760 t.	10, i.e. 150 t. Fatigue of bridges: *a*) 80 %, *b*) 7 %, *c*) 13 %.	Local circumstances.
Tunisian Rys. .	< 10 m. 1 770 2 060 t. / > 10 m. 230 11 960 t.	...	Replacement by concrete slabs in the case of small bridges. Reinforcement or replacement of large bridges.

ADMINISTRATION.	QUESTION No. 1	2	3
Djibouti to Addis-Ababa . . .	< 10 m. 964 2 000 t. > 10 m. 147 3 000 t.	Resources to be devoted to reconstruction in the years to come.	Reinforcement on site to avoid the cost of handling and interruption of traffic.
Greece	< 10 m. 1 610 3 750 t. > 10 m. 321 10 060 t.	. . .	. . .
Luxembourg . .	< 10 m. 81 } 5 200 t. > 10 m. 52 }	. . .	. . .
Norway	< 10 m. 1 850 7 000 t. > 10 m. 600 48 000 t.	400, i.e. 600 t. Increased loads : *a*) 100 %.	. . .
Holland	2 500 (120 movable). 180 000 t.	Increased loads : *a*) 90 %, *b*) 10 %.	Economic balance sheet : small bridges strengthened by reinforced concrete slabs. Reinforcement is expensive, obstructing, and involves retaining a weak bridge made of old metal.
Portugal	< 10 m. 552 1 040 t. > 10 m. 362 51 370 t.	30, i.e. 2 300 t. Increased loads.	Financial balance sheet.
Rumania	. . .	Reinforcements : 670 t. (reconstruction 19 500 t. in 5 years). Stepped adaptation to increased loads planned for the lines (divided into 4 categories).	Reinforcement up to 30 % additional metal; replacement after this figure.
Sweden. State Rys. . . .	< 15 m. 2 850 18 000 t. > 15 m. 750 80 000 t.	100, i.e. 3 750 t. Increased loads, widening the track.	Financial balance sheet. Replacement in the case of small bridges, reinforcement being expensive in spite of the saving in metal and making it impossible to incorporate certain valuable improvements (width, etc.).

ADMINISTRATION.	QUESTION No.		
	1	2	3
Oxelösund - Flen - Västmanland . .	< 10 m. 21 85 t. > 10 m. 26 980 t.	...	...
Stockholm-Roslag	< 10 m. 48 130 t. > 10 m. 13 1 500 t.	...	...
Switzerland.			
Federal Rys. . .	< 10 m. 302 > 10 m. 304 } 51 950 t.	750 t. Increased loads, electrification, technical imperfections. *a*) 100 %.	As the bridges have already been strengthened, a further strengthening on site which could only be done in the case of small bridges, would be expensive and of doubtful value. Replacement is usually necessary.
Rhaetian Rys. .	105	No reinforcement in view.	...
Czechoslovakia . .	< 10 m. 3 852 > 10 m. 1 342	22, i.e. 2 000 t. *a*) 98.5 %. *b*) 1.5 %. Increasing the capacity of small lines.	Bridges older than 50 years are replaced; reinforcement is limited to parts of the table in the case of bridges less than 50 yrs. old. In other cases, replacement.
Turkey	> 10 m. 1 060 66 000 t.	2 500 t. Age of the bridges. Increased loads: *a*) 72.5 %, *b*) 12.5 %, *c*) 15 %.	Technical and economic balance-sheet.

SECTION II. — Regulations concerning the theoretical limit of safety.

QUESTION 4. — *What rules do you apply to determine the strength of existing metal bridges? Are these rules laid down by the Authorities or only by the railways itself? Are there any differences between the rules for the calculations of new bridges and those for existing bridges?*

QUESTION 5. — *To determine the strength of existing bridges, do you make use of calculations, or the direct measurement of the stresses, or a combination of the two? Please give detailed particulars of the methods used. State the overload taken into account, and if it is the same or not on all the various lines of your system.*

QUESTION 6. — *Do you check the calculated stresses by actual observations using extensometers? When the two figures disagree, which do you consider gives the true picture of the strength of the bridge? Explain the reasons for your choice.*

QUESTION 7. — *Under what circumstances and to what extent do you allow higher overloads than those permitted by the rules (for example relief trains, diversions, exceptional loads)?*

Administration.	Question No.			
	4	5	6	7
Austria . .	Ministerial regulations : 10 % increase allowable on the stresses applicable to new bridges.	Usually by calculations, but by measurement if needs be, tests of the metal.	Sometimes the results obtained by measurement are used.	In the case of exceptional loads, 10 % tolerance is allowed from time to time.
Belgium and Colony S. N. C. B.	Railway regulations : The limits vary according to the kind of bridge, the metal, and the traffic.	Calculations, observations of the bridges and measurement of the versines.	...	Speed restrictions for exceptional transports.
Belgian Light Rys.	Regulations of the Roads & Bridges Administration. The trial train is heavier than the trains in current service.	Calculations, and in exceptional cases measurements of the stresses.	...	...
Lower Congo to Katanga . .	14 kgr./mm² (8.889 tons per sq. inch) under typical trains.	...	...	...

ADMINISTRATION.	QUESTION No.			
	4	5	6	7
Spain . . .	Existing bridges : Stress, iron 6 kgr./mm² (3.809 tons per sq. inch). Deflection : $\frac{l}{1\,000}$. Number of pairs of wheels and load per lineal metre lower than on new bridges.	Calculations and measurement. The overload varies from line to line.	Calculations and measurements are continued until they agree or the reason for the disagreement is discovered, and this is made the subject of a special examination.	Speed restrictions.
Finland . .	Railway regulations. The limiting stresses are sligthly higher than for new bridges.	Calculation.	Exceptionally if the two results do not agree, priority is given to observations on site.	Special cases, speed restrictions.
France and Colonies S. N. C. F.	Ministerial circulars of 1927 (new bridges) and 1930 (existing bridges). Calculation on the same lines as for new bridges, the value of the limiting stresses being increased to 2/3rds of the elastic limit of the metal, i.e. as a general rule 14 kgr. (8.889 tons per sq. inch) for iron and 18 kgr. (11.43 tons per sq. inch) for steel instead of 13 kgr./mm² (8.254 tons per sq. inch). The overload considered is the maximum overload allowed on the line.	If the calculations give stresses between 2/3 and 4/5 of the elastic limit, the results obtained by measuring the stresses by extensometer are used.	If there is disagreement between the calculations and measurements, attempts are made to discover why this is so, and calculations or measurements are made once more in order to make the results agree, which is usually achieved.	In the case of relief trains or exceptional diversions, the limiting stresses may be exceeded by 10 %, with if needs be a reduction of the speed to 30 km. (18 miles)/h., the dynamic increase is reduced by half, and omitted at 10 km. (6 miles)/h.
Paris Metro. . . .	Ministerial circulars of 1927 and 1930. A typical train of 420 t. or the heaviest train run.	Calculations and measurements of the stresses as a check.	No formal rules of interpretation.	No exceptions allowed.
Algerian Rys. . . .	Ministerial circulars of 1927 and 1930.	Calculations and measurements of the stresses (3 categories of lines).	Actual stresses.	Exceptional loads are allowed giving stresses exceeding the limiting stresses by 10 %.

Administration.	Question No.			
	4	5	6	7
Gafsa Rys.	Axle loads of 10 t. according to the Regulations of 1891 compared with 16 t. for new bridges.	Calculation. Trains with axle loads of 10 t. and 13 t.	...	Exceptional loads giving rise to increased stresses up to 40 % are allowed.
Tunisian Rys. . . .	Ministerial circulars of 1927 and 1930.	Measurements of the deflection and stresses, under actual trains.	The results given by measurements are retained when these are lower than the calculated amounts.	Traffic is only allowed on doubtful bridges under very exceptional circumstances; in such cases speed restrictions, single track working, and restrictions on the attachement of heavy wagons are imposed.
Djibouti to Addis-Ababa . . .	Regulations contained in the circular of 1927 applicable to new bridges but taking the actual load instead of the typical overload.	...	...	Very exceptionally trains are allowed to run when the stresses exceed 18 kgr. (11.43 tons per sq. inch). The speed is restricted to 5 km. (3 miles)/h. for 16 kgr. (10.16 tons per sq. inch) and 15 km. (9 miles)/h. for 15 kgr. (9.523 tons per sq. inch).
Greece . .	German regulations.	Calculations only.	...	...
Luxemburg .	German G train regulations.	...	...	Altogether exceptional. The coefficient of impact is reduced to 1.1 with V = 10 km. (6 miles)/h.
Norway . .	Railway regulations. There is no difference in the stresses allowed for old and new bridges.	Calculation. Two typical trains are used according to the lines.	...	Reduction of the dynamic increase for reduced speed.

ADMINISTRATION.	QUESTION No.			
	4	5	6	7
Holland . .	The railway regulations are similar for old and new bridges; if the former do not meet the typical overload requirements, they are checked under 9/10 of the typical overload, and even under the heaviest locomotives in use, and if needs be under machines which load the weak structure effectively.	Calculation; verification only in the case of high stresses; static (Okhuizen) and dynamic extensometers of variable capacity.	...	Tolerances in certain cases depending on the age of the bridge, the metal, the most worn main girders, and the frequency of the overload.
Poland . .	Primary stress allowed : steel : 15 kgr./mm² (9.532 tons per sq. inch) ; iron : 14 kgr./mm² (8.889 tons per sq. inch) under the real overload in the case of existing bridges; under typical trains in the case of new bridges.	Overload varying according to the line.	...	Coefficient of dynamic increase suppressed when V = 10 km. (6 miles). Tolerance of 2 kgr./mm² (1.269 tons per sq. inch) in the stresses on bridges with plain webs.
Portugal . .	State regulations : Similar stresses for new bridges and existing bridges : iron : 10.5 kgr./mm² (6.666 t. per sq. inch), steel : 14 kgr./mm² (8.889 t. per sq. inch) without exceeding 60 % of the elastic limit or 36 % of the breaking strength.	Actual overloads. Measurements of stresses are considered.	...	No tolerance.
Rumania. .	Provisional State Regulations. Limiting-stress 14 kgr./mm² in the case of new bridges; 15 kgr./mm² primary stresses only in the case of existing bridges.	Varying overloads according to the lines (4 categories). Calculations and measurements.	...	Exceptional loads: reduction of the dynamic increase.
Sweden. State Rys.	State regulations : The same regulations apply to new and existing bridges, except that the coefficient of dynamic increase is independent of the speed in the case of new bridges and reduced to low speeds for the existing bridges.	Calculation. Measurement of the stresses. Three systems of overload according to the importance of the lines.	The measurements are retained when they are less favourable than the calculations.	Reduction of speed. Restrictions of the loading gauge. Sometimes increase of the tensions allowed up to 20 %.

Administration.	Question No. 4	5	6	7
Oxelösund-Flen-Wästmanlands .	New bridges, type A (20 t.). Existing bridges, type B (18 t.).	...	...	...
Stockholm-Roslag . .	Ditto. The real loads are only 80 % of type B.	Calculation.	...	...
Switzerland .	Federal Ordonnance. The same limiting stresses for new and existing bridges. Effective overloads for existing bridges, typical train for new bridges.	Calculation, then static and dynamic testing; in principle 2 categories of overload: standard gauge or narrow gauge. If needs be load limited per axle or per lineal metre. Reduction of the speed to reduce the dynamic effects.	Observations (deflections, static and dynamic stresses, gradual deformations) are used to correct if needs be the results shown by calculations.	In isolated cases for exceptional transports, the limiting stresses may be exceeded by 20 % when the excess is due to the axle load and not to the average load.
Czechoslovakia . . .	Regulations imposed by the Ministry of Transport. Checks are carried out on the same lines as those used when building the bridge: the overloads are the effective overloads, varying according to the lines.	Calculation; sometimes measurement in the case of elements the calculations of which are hypothetical and uncertain.	Only in the case of bridges when the estimated figures for the housing are doubtful. In well determined cases, the results of experience are retained.	Exceptionally, tolerance of 10 % for the overload. With speed restrictions the dynamic increase is reduced to 10 % in the case of small bridges and 5 % in the case of large bridges.
Turkey . .	German specification. B. E. 15/6/36. The limit allowed is fixed according to the results obtained from tests of the metal.	Calculation and measurement of the deflections. Typical overload.	...	Exceptional overload. Supplementary deflection up to 5 %.

SECTION III. — Actual strength of metal bridges.

QUESTION 8. — *Do you know of any bridges which whilst meeting the maintenance regulations were in fact unable to stand up indefinitely to the traffic over them? If so, please give in detail the observations made and the probable causes.*

QUESTION 9. — *Have you had any breakages of metal bridges which could be attributed to vibrations, or to fatigue of the metal, to the poor quality of the metal, or to defective construction? If so, please give full details.*

QUESTION 10. — *As a general rule when do you think a bridge should be closed to traffic? Should it be closed when it shows :*

a) *any permanent deformation, a deformation of a certain value, or the breakage of a part of the bridge?*

b) *excessive elastic deformation under overload?*

c) *other anomalies? If so, what?*

Do you allow bridges with permanent general deformation or only deformation of certain parts to be used? Under what conditions?

QUESTION 11. — *Do you think that your regulations concerning the maintenance of metal bridges in service could be widened, taking into account present conditions? Please state in what way you think they could be altered and why.*

ADMINISTRATION.	QUESTION No.		
	8-9	10	11
Austria	Local breakages due to defective construction (no webs on the stringers, insufficient rivetting).	If permanent deformation occurs or a main part is broken, traffic is forbidden or speed and load restrictions imposed.	No.
Belgium & Colony.			
Belgian Nat. Rys.	Cracks discovered after the war (no doubt due to explosions).	Limitations to the load are determined by the state of the bridge, its constitution and the quality of the metal.	It is advisable to replace without delay any bridges considered inadequate to meet the maximum operating requirements.
Belgian Light Rys.	...	If corrosion has increased the limiting stresses to 120 %, reinforcement or replacement of the element takes place.	...

Administration.	Question No.		
	8-9	10	11
Spain	Defects of the metal due to recristalization or segregation.	Bridge closed for permanent deformation three times the elastic deformation or for elastic deformation double the normal value or when an important part breaks. Speed limited to 6 km. (4 miles)/h. if it is absolutely necessary to keep the bridge open to traffic.	No.
Finland	Breaking of the diagonals on a bridge over the river Aura.	When there is permanent deformation or breakage. In the case of permanent deformation it is possible to allow loads below the value which gave rise to the deformation.	No; they should be completed in so far as the defects resulting in the bridge being closed to traffic are concerned.
France & Colonies.			
S. N. C. F. . . .	Cracking of the joints of stringers and struts. Cracks in the trellis girders starting near the rivet holes.	Accidental slight permanent deformation does not involve traffic restrictions, but the breaking of any part affecting the strength of the bridge does so. Excessive elastic deformation can lead to speed restrictions for safety reasons; as would vertical or horizontal oscillations of excessive amplitude. There are some bridges with very definite permanent deformations which have been kept in use without any reinforcement.	...
Algerian Rys. . .	Insufficient cross-bracing (rivets missing, cracks at fastenings).	Permanent deformation involves a special examination being carried out.	...

ADMINISTRATION.	QUESTION No.		
	8-9	10	11
Gafsa Rys. . . .	Broken webs and angles of stringers.	Any permanent deformation leads to the bridge being closed to traffic.	In special cases account should be taken of the real quality of the metal.
Tunisian Rys. .	Fractures in the web near the bearings of small bridges in I PN.	...	...
Djibouti to Addis-Ababa . . .	...	If there is permanent deformation an examination is carried out; if not very extensive the speed is restricted to 5 or 15 km. (3 or 9 miles)/h. and the bridge kept under observation.	...
Holland	Cracks in the webs of girders near where the fastenings of the struts are welded (the section of the fastening may have been made too small).	The bridge is not necessarily closed if the deformation is slight; but usually is if there is any fracture. Too large an elastic deformation will not lead to the bridge being closed.	No.
Poland	...	After permanent deformation the bridge is either closed or the load restricted.	...
Portugal	Cracks in the angles of stringers (defective metal in the web) loosened rivets, cracks in the struts when the side pieces of the fastenings are insufficient.	Traffic restrictions in the case of fractures, permanent deformation, or excessive elastic deformations.	The favourable results obtained by measurements might be taken into account.
Rumania	No structural modification of the metal in bridges nearly a hundred years old. Two military bridges collapsed under prolonged traffic with stresses exceeding the fixed stresses by 50 %. Flaking of puddled iron, never disquieting.	Such cases have never arisen except owing to war damage or as a result thereof (loads exceeding the permissible loads, undermining of supports). The deformed parts have been repaired and traffic assured by shoring up, forbidding locomotives, etc.	...

ADMINISTRATION.	QUESTION No.		
	8-9	10	11
Sweden.			
State Rys. . . .	Fracture of a diagonal of the cross bracing fastened by welding during reinforcement of the bridge. Cracks in the fastenings of old stringers (quality of metal, fatigue).	The bridge is closed when there is excessive permanent deformation or a serious fracture. In the case of excessive elastic deformation, restrictions are imposed on the load and speed.	All the necessary consolidations have not been achieved.
Oxelösund - Flen - Västmanland . .	No.	...	The regulations should be made more flexible.
Stockholm - Roslag	...	Traffic can be allowed across bridges with permanent deformations providing the load and speed is limited according to circumstances.	...
Switzerland . . .	Local alterations due to defects in construction, the quality of the metal, aging of the metal. Cracks in the stringers and stays near the fastenings, in the struts under the longitudinals, in angles near the supports. Cracks in the narrow parts of angles; fracture of the bearing plates. Fracture of a newly welded longitudinal due to the combined effects of internal tension and dynamic stresses.	The bridge is closed when there is progressive permanent deformation or a fracture; bridges with local deformations have been kept in service. The maximum elastic deflection under load should not exceed one thousandth of the span (tolerance of 10 % on lines with little traffic).	Such questions are examined in the finest detail; defects are submitted to specialists who examine the bridge and sound it, so as to discover its real strength.
Czechoslovakia . .	Deterioration of the angles of the longitudinals without pads. Fractures in welds and outside the welds of girders of provisional bridges formed of rolled sections strengthened by welded plates or welded girders welded end to end.	The elastic deformation should not exceed 10 % of the calculated deformation and the permanent deformation should not exceed 20 % of the calculated elastic deformation; measurements have never led to these rules being brought into use. The bridge is closed when any part affecting the strength is broken.	New regulations are about to be published.

ADMINISTRATION.	QUESTION No.		
	8-9	10	11
Turkey	...	The bridge is closed if any important parts are fractured. If there is any permanent deformation, the bridge is kept under supervision, samples of the metal are examined, etc., and if needs be the bridge is closed. Traffic restrictions are imposed if the intermediate piers of continuous girder bridges settle, and if there are elastic deflections exceeding $\frac{l}{900}$ in the case of mild steel and $\frac{l}{700}$ in the case of 52 steel.	A table of loads corresponding to the maximum loads on railways throughout the world should be prepared. Regulations should be drawn up for stresses and deflections permissible on bridges made of steel of greater tensile strength than A.37.

SECTION IV. — Removal and re-use of metal bridges.

QUESTION 12. — *Give details of cases in which a metal bridge has been taken down and strengthened for re-use. In each case please supply the following information :*

a) *Photographs and drawings showing the general layout of the bridge.*

b) *Photographs and drawings showing how it was taken down and reassembled (specify if the bridge was removed as a whole or in sections).*

c) *In the case of reinforcement, was the bridge taken to the shops or to a specially equipped yard?*

d) *Describe the method of transport to the yard or shops and the return journey to put it in position.*

e) *Was the whole bridge re-used or only part of it?*

f) *Was the bridge re-used in the same place or in another part of the railway? for another purpose?*

g) *If it was re-used on the same site, how were the trains run while it was being reinforced?*

h) *Was the bridge reinforced to restore it to its original strength or to enable it to carry higher loads?*

i) *Where any of the original layouts altered?*

j) *Why was the work done in this way?*

QUESTION 13. — *Is it the current practice on your Railway to reinforce in this way :*

a) *small span bridges,* b) *large span bridges,*

according to a programme drawn up several years in advance?

In addition, when bridges are replaced do you keep in stock the parts that are in a good state of repair in view of their possible re-use in the future? Please give details on this point. When you draw up a replacement programme, what limits of span are usually laid down (upper and lower)?

Administration.	Question No.	
	12	13
Belgium & Colony.		
Belgian Nat. Rys.	Parts of some trellis girders damaged in 1940 have been re-used in building other bridges in the shops.	...
Spain	...	Sometimes re-used as scaffolding components. The programme of work which is drawn up to suit the line does not lend itself very well to re-use.
Finland	Forty years ago old bridges were removed to new lines without alteration.	Several bridges have been transferred and used to carry roadways.
France & Colonies.		
S. N. C. F. . . .	Bridges from secondary lines or those taken out of service are re-used. Reutilisation of auxiliary bridges remaining available after the reconstruction of the supporting pillars. Taken up, repaired in the shops and re-erected, either on the same site or elsewhere in the case of small bridges of identical size and type.	Practice made use of when the technical and financial accounts show it to be advantageous; relatively easy in the case of small bridges; in the case of large ones, a careful investigation is required after detailed examination of the condition of the bridge.
Gafsa Rys. . . .	10 and 15 m. (32′9¾″ and 49′2½″) bridges on mining sidings have been reinforced either on the site or in the shops. Transported on flat wagons and re-used as a whole, often on the same site. A temporary bridge is used while the other one is being repaired and strengthened.	Current practice, the subject of programmes in the case of 4 to 15 m. (13′1½″ to 49′2½″) bridges.
Tunisian Rys. .	Damaged bridges on metre gauge lines are replaced by bridges removed from standard gauge branch lines no longer in use, the track being carried on the decking by means of rubber packings and bearing plates.	...

ADMINISTRATION.	QUESTION No.	
	12	13
Djibouti to Addis-Ababa . . .	4 bays of 12 m. (39′4½″) span were taken on flat wagons to the railway shops; reinforced, and held in stock till they were re-used in place of another similar sized bridge. These bridges were in a very bad state of repair and could not be allowed to remain in use.	Exceptionally.
Greece	Some small bridges reinforced after having been shifted on the side space, and re-erected.	. . .
Holland	Seventeen 28 m. (91′10³/₈″) bridges of 2 bays situated side by side on shunting lines on a very busy line were taken up, repaired and altered, then re-erected. A special wagon was built to enable a bridge to be replaced quickly by a strengthened bridge (1¾ hrs.).	Exceptionally in the case of small bridges.
Poland	A double track 88 m. (288′8⁵/₈″) long bridge was taken down and altered into a single track bridge of the same span without the girders being reinforced.	An altogether exceptional practice.
Rumania	Sound and well made bridges removed from higher category lines according to a programme for improving the lines are used again on lines of a lower category where they can give useful service for many years. As it is not known beforehand where they will be re-used, the bridges are held in stock after being taken down and the parts numbered. They are subsequently taken to the new site and reassembled as required after strengthening the sections of certain parts.	It is the usual practice to use bridges removed from main lines on secondary lines without reinforcement.
Sweden.		
State Rys. . . .	Sometimes small bridges have been held in stock after being taken down and later on re-used at another place without reinforcement.	Not a very common practice. The reinforcement programme aims at obtaining a satisfactory degree of strength on all the bridges of the line; it is difficult to re-use them without reinforcing them and reinforcement is too expensive.

Administration.	Question No. 12	Question No. 13
Switzerland . . .	A bridge built in 1894 with three bays of 26, 31 and 26 m. (85′3⅝″, 101′8½″ and 85′3⅝″) span of insufficient strength for an electrified line, adapted for single track working, divided up into sections in 1924 according to the crane capacity available, removed and re-erected laterally on its new site, reinforced (new longitudinals, braking frame, reinforcement of the gussets of the struts), then lined up with the bridge it was to replace. A 30 m. (98′5⅛″) bridge was reinforced by doubling the main girders by girders from similar bridges which had been replaced. Old girders have been re-used, the depth of the web having been increased by cutting and welding in the shops, for the main girders of bridges with concrete tracks built around a temporary bridge.	The position regarding the reinforcement of bridges and the tendency to replace small bridges by bridges with encased girders has resulted in the components of old bridges not being re-used, except when there is a shortage of metal for certain parts. Thus, during the war, certain rails, in particular from the framework of old bridges, were used for the reinforcement of reinforced concrete slabs.
Czechoslovakia . .	A 55 m. (180′5⅜″) metal bridge moved to an adjacent embankment, was divided up and taken to another site where it was re-erected with additional cross bracing.	An altogether exceptional practice.
Turkey	A 52 m. (170′7¼″) metal bridge was taken down, marked and sent by wagon to the site where it was to be re-used. It was made into a two bay bridge after the plates and adjoining girders of the new supports had been reinforced as well as the horizontal cross bracing. The bridge could then carry trains with axle loads of 20 t. The main reason this work was undertaken was the shortage of metal.	Bridges taken out of service are re-used to some extent for less important railway bridges, after being held in stock till required.

SECTION V. — Methods of reinforcement.

QUESTION 14. — *Generally speaking do you reinforce metal bridges :*

a) *by repairing and strengthening the section of components?*

b) *by adding other components or complete frameworks which modify the elastic function of the bridge (for example : successive spans turned into a single continuous span and carried by intermediate supports, addition of diagonal bracing or struts, addition of new structures [in metal, reinforced concrete, or masonry] to which the old bridge is connected, etc.)?*

QUESTION 15. — *Give examples of 14 b). How are the stresses due to the dead weight and those resulting from the loads divided between the old and new structure? Do you try to free the old structure from the dead weight? Are you satisfied with the ease with which your method can be employed (please give details) and the results obtained?*

QUESTION 16. — *When strengthening the section of components, how are the stresses due to the dead weight and to the load divided between the old and new metal, especially if the two metals are of different kind? Do you use any special method to free the old metal from the dead weight? What method? What do you think of its ease of application and the results obtained?*

QUESTION 17. — *If the strengthening of weak components enables them to carry higher loads than those the bridge ought to take, do you also strengthen the other parts (which otherwise would not need reinforcement), so as to obtain a stronger bridge as a whole?*

QUESTION 18. — *Give full details concerning any method of prestressing the framework or components which you have been able to employ in strengthening metal bridges, in particular to modify the distribution of the stresses between the different parts of the bridge.*

QUESTION 19. — *When certain parts, for example beams under tension, have developed play and thus no longer carry the load they should, what method do you use to correct this (shortening by heating to a suitable degree, cutting and repiecing, replacement, etc.)?*

QUESTION 20. — *When it is question of strengthening bridge components, when do you prefer to use rivetting and when welding? For what reasons? Do you use electric arc welding exclusively for adding the metal?*

ADMINISTRATION.	—				Q
	14-15	16-18	17	19	2
Austria	*a*) On bridge parts; the new metal only carries the load. Neither *a*) nor *b*) on main girders (2 cases only in 50 years).	...	...	...	Electr weldin metal main g
Belgium & Colony. S. N. C. B. . . .	*a*) Added with unrivetting the old parts. *b*) Addition of struts.	...	...	Sometimes stressed components added to carry all shear stresses.	Weldi avo especia the c iron.
Belgian Light Rys.	...	...	Limited to what is necessary.	...	Rive prefe

QUESTION 21. — *How do you weld flats on to rivetted parts (difficulties due to the rivet heads)? Do you find the work easy to carry out and the results satisfactory?*

QUESTION 22. — *What experience have you had in repairing corroded rivet heads or sections by means of metal added by welding?*

QUESTION 23. — *What experience have you had of welding puddled iron and high tensile steel?*

QUESTION 24. — *What difficulties have you encountered in strengthening bridges by welding? Do you know of any fractures occurring in components reinforced by this method? Do you carry out trials or checks on welds :* a) *on site,* b) *in the works?*

QUESTION 25. — *What is the maximum percentage of metal you consider can be added to a component in order to strengthen it? Is this percentage the same in the case of rivetting and welding? Give some examples.*

QUESTION 26. — *Have you used high tensile steel or special metals to reinforce metal bridges? Give full details. What advantages or drawbacks have you found in using such metals for reinforcements?*

QUESTION 27. — *When you recondition corroded components, what method do you use to fill up the hollows and prevent further corrosion?*

QUESTION 28. — *Have you reinforced any parts by encasing them in concrete or reinforced concrete? Give examples. What method do you employ to assure adhesion between the metal and concrete? Has it given complete satisfaction?*

1	22-24-27	23	25	26	28
.	27) In one case corrosion was made good by adding new metal; the process was not developed.	...	Formerly 30 %.	...	Two bridges have been encased to protect them from rust; adhesion was improved by pins or studs. The process was not developed.
.	...	...	...	...	...
parts of profile ney can in posi- without rivets in the	...	...	...	...	Encasing of a lower member which was corroded with the addition of sufficient steel bars. The bridge has been satisfactory since 1922.

ADMINISTRATION.	14-15	16-18	17	19	
Spain	*a*) Only in the case of steel bridges. Addition of crossbracing.	...	Limited to the immediately necessary.	...	Rivet princ ing used ting invol scaff
Finland	...	...	Limited to what is necessary.	...	Rivet site ely.
France & Colonies. S. N. C. F. . . .	*a*) Current practice. *b*) Construction of an intermediate pier. Addition of supplementary girders, arches or cables, reinforced concrete slabs. When assembling an attempt is made to have all or part of the dead weight carried by the new framework.	To alter the distribution of the stresses on old and new bridges, simple operations of limited extent are needed. The adjustment of the supports according to very exact limits has given good results. Temporary tension pieces are used when putting the diagonals in place.	Considerable reinforcement if possible.	Cutting and piecing together as a general rule.	Questi on i merit ing enal cost ing t to b and sectio used the dange due being Rive the small jobs w not looke
Paris Metro. . .	*a*) Difficulty of freeing the old structure from the dead weight in the case of large bridges where it is advantageous to do so.	No interest in using a metal of greater resistance in reinforcing sections.	General reinforcement.	...	Arc w Ease bly, havin move Tight and

:1	22-24-27	23	25	26	28
enough set as sary to d the	24) No fractures nor damage has occurred with welding. 27) Cleaning and painting with red lead.	...	Same percentage with rivetting and welding. Reinforcement limited to an additional thickness of 12 mm. ($^{15}/_{32}$″).	...	Small bridges (less than 10 m. = 32′9$\frac{3}{4}$″) have been encased. Good results as far as maintenance is concerned but the old metal is obviously not utilised to the maximum.
..	...	...	...	...	...
Discontiwelds in to avoid heads. orated .	27) Corroded sections reformed by welding. Reinforcement plates are used with plastic material interposed. Sealing casing.	Local breaking away when the welds were too heavy. Technique not well understood.	The addition depends on whether it is possible to make attachments or to weld. It is not possible to add too thick layers to thin sections. Welding takes less metal for reinforcements.	Only one example.	Girders of steel, cast iron or iron. Addition of blocks underneath and above the arch. Concreting of small trough-shaped bridges. Adhesion improved by cross rods, welded rods, studs.
to avoid vets.	22) Since the rivet heads have not to be reformed, replacement is easier. 24) Difficulty of welding mild Martin steel; internal stresses, suitable layout of the assembly, choice of method of execution. Checked by milling to find out the quality of the weld. 27) Hollows filled in, ground down, continuous welding filets.	...	25 to 65 % according to the parts. Welding needs 10 to 15 % less metal for reinforcing.	High tensile steel is without advantage for reinforcement.	...

ADMINISTRATION.					C
	14-15	16-18	17	19	
United Rys. . .	...	...	...	...	Ele wel
Algerian Rys. . .	...	Dead weight carried entirely by old metal.	...	Cutting or replacement.	Weldi reasor nomy of exe
Gafsa Rys. . . .	...	The old and new metals co-operate in carrying the load.	If there is not much reinforcement to be done, nothing else is done.	...	Rivettin does volve r rivets. ing i makes sible t removi ets, or of ex or if less.
Tunisian Rys. .	*a*) Current practice. *b*) Doubling the main girders, stays and longitudinals, two separate spans made into one by means of intermediate piles. The actual distribution of the load corresponds to the theoretical distribution according to the measurements made.	The old and new metals co-operate in the strength according to their section and coefficient of elasticity.	Limited to what is necessary.	...	Accordi cost, a ing on
Djibouti to Addis-Ababa . . .	...	...	According to the merits of the case.	...	Rivettin to the culty c nising depots to shor staff a terials.

:1	22-24-27	23	25	26	28
..	24) No incidents with bridges repaired by welding.	...	...	...	...
ing of plate the edge en the f rivets.	27) Packing with red lead.	...	Stays 60 %. Stringers 80 %.	...	Cast iron viaduct with four 50 m. (164′½″) spans; one 45 m. (147′7¾″) cast iron arch, upper and lower reinforced concrete slabs. Cross bracing one iron 50 m. arch with slabs under the track, for slabs under and over the arch near the springings. Excellent results.
is taken oid weld- near the .	24) Work on site is difficult; checks can be carried out in the shops. 27) Packing with red lead and white lead.	...	40 %. In the case of the fastenings, welding saves metal.	...	...
e case of is bars are weld- tween the of rivets wo ribs ne edges.	24) Difficulties in carrying out the work, welds on the roof and on the uprights without serious irregularities. No breakages reported. 27) Bearing plates flaking away by rust; edges scrapped thoroughly, to get clean metal and welded.	Satisfactory results in provisional reinforcements after war damage (bars of 42 steel replaced by 72 kgr. [158 lbs.] rails).	According to the parts : Bridge components: 50 %. Stringers : 80 %. Bridge as a whole 20 %. With rivetting the additional weight is greater.	...	...
...	27) Built by welding in the shops.	...	35 %.	...	...

ADMINISTRATION.	14-15	16-18	17	19	G
Greece	*a*) and *b*) Doubling the main parabolic girders without interrupting the traffic.	No precautions taken to free the old structure from the load; the additional strength given by the reinforcements is moreover greater than that needed.	...	...	
Norway	...	...	...	Replacing rivets, cutting and piecing together.	
Holland	Neither *a*) nor *b*). Any bridges of insufficient strength are replaced completely.	...	...	Systematic local heating after the section has been held.	Weldin the ba is suit avoidi sets traffi
Poland	*b*) Exceptionally, doubling the girders by means of girders taken from identical bridges taken out of use. The old bridge has been raised in order to free it from the dead weight, the connections first of all being made by means of bolts : an easy and satisfactory job.	...	Reinforced as a whole.	...	Arc when sible plates distur rivets ting cases.
Portugal	*a*) and *b*) In the case of iron the limit of 10.5 kgr./mm² (6.666 tons per sq. inch) means that reinforcement involves heavy sections and is generally expensive.	The new metal carries the load only.	Reinforcement limited to what is essential.	The bars are replaced.	Rivettin ing existin as far sible.
Rumania	*b*) Exceptionally metal arches are added underneath. The load is not taken off the old structure; the operation is expensive owing to the scaffolding required; the results are of doubtful value.	...	Reinforcement to take the typical train for the line.	...	Rivettin The of cor the qu the w consid solvab

21	22-24-27	23	25	26	28
...	...	...	...	...	...
...	27) Cleaning and repainting.	...	...	...	...
...	24) No difficulties experienced. Important welds are checked by means of X-rays. 27) Brushed down and painted with red lead.	Cracking parallel to the fibres.	Depends upon particular cases.	...	...
...	22) No breakages of welded parts. 24) Welds are checked in the shops by means of X-rays. 27) Cleaned and painted.	...	...	...	...
...	...	...	35 % for economic reasons.	...	...
...	27) Replacement of damaged parts.	...	30 % (50 % during reconstruction periods).	...	...

ADMINISTRATION.					Q
	14-15	16-18	17	19	2
Sweden.					
State Rys. . . .	*b*) Exceptionally. A parabolic girder bridge was turned into an arch bridge, by adding another girder below and doing away with the diagonals; reinforcing straight bridges with full web by introducing intermediate supports resting on a lower arch made of concrete; during construction the old dead weight was transferred to the new structure.	The new metal only carries the load, the difference is small in the case of little bridges. No systematic prestressing.	Endeavours are made to carry out the reinforcement in such a way that the bridge is a homogeneous unit, in so far as this can be done at a reasonable cost.	Usual processes. The holes in the bar and in the gusset are reamed out separately and drifted. The new tensioned bars are made sufficiently rigid.	In the riv bridge ting Weldi used t the tre nor th bracin
Switzerland.					
Federal Rys. . .	*b*) Additional arches over or under, stressed by means of uprights. Doubling of the main girders. Addition of diagonals to triangulate an arch, addition of uprights to the diagonals, etc. The reinforcement as a general rule is only stressed by the load.	...	...	...	Arch we reinfor tions. force etted ings, r is pre (doubt tributi tween ets and

1	22-24-27	23	25	26	28
..	27) Welding to build up hollows but the method is not very satisfactory owing to the stresses set up in the structure.	...	Limited by financial considerations rather than technical reasons; by a small percentage, reinforcement costs more than replacement.	No.	Certain encasings carried out a long time ago have not given any cause for criticisms on ordinary inspection and seem likely to have a normal expectation of life. There is however a doubt concerning the effectiveness of encasing from the point of view of corrosion in the neighbourhood of the inevitable cracks, and owing to the difficulty of ascertaining the state of the metal and making repairs.
reinforcement plates all bearing between rows of rivets along bench.	24) Difficulties due to the position of the welds and the difficulty of preparing the work in bad weather. Difficulty of adjusting flat plates on existing plates. Difficulty of following a definite order in making the welds to avoid undue residual stresses. The welds stand up well as a general rule. A few cracks have appeared either owing to dynamic stresses, or at the points where the secondary stresses are concentrated; checks are carried out by means of control samples, by examining the welds by means of a magnifying glass and sometimes in the shops by X-rays. 27) Grinding and painting with red lead, with putty to fill up bad places.	Frequent cracking when doing the work. After remaking bridges on lines with light traffic behave correctly. Bridges of 44 steel have been welded.	Addition frequently limited by difficulties in attaching the bars or the strength of the webs. The section must not be altered too much to avoid secondary loads. Too heavy runs of weld metal must be avoided or these set up large stresses.	...	In new bridges the adhesion is improved by welded pieces, hooks, coils, or straps.

ADMINISTRATION.	14-15	16-18	17	19	
Czechoslovakia . .	*a*) Addition of bearing plates to the struts and stringers, while raising up the track (rail packings). *b*) Addition of struts to relieve the longitudinals.	About 1900, gins were placed under the joints or stays of trellis girders to be reinforced and they were raised by means of wedges in order to free the parts from the load.	...	The bars are heated on a cross band 10 cm. ($3\,^{15}/_{16}$″) wide and got into the proper position with a mallet; the the process is repeated at regular intervals along the bar relatively to the joints the bars cross, at regular intervals where there are crossings. The holes are also made oval and wedges fitted across them before re-rivetting. They are replaced by more rigid bars.	Rivet we onl occ owi sho skil and conf rivet
Turkey	*b*) By introducing an intermediate support of metal construction. The distribution of the stresses is modified as required.	If the old structure can be supported during the work of reinforcement, the dead-weight is distributed between the old and new metal.	No slight reinforcements are carried out; it is better to err on the generous side rather than risk damaging the metal.	...	Rivett in th the whe wel used con that lea weak the sectio

21	22-24-27	23	25	26	28
s drilled uired for vet heads hollow filled in lding.	24) Rolled girders reinforced by bearing plates welded longitudinally; before the provisional bridge was put in place: the bearing plate, flange and web were fractured along a length of 175 mm. ($6\,^{57}/_{64}$″); in the girder end welded, fracture of the plate extending into the web; in the girder end welded, fractured weld. All these incidents occurred in the girders of provisional bridges and were due to faulty welding. 27) A thick layer of red lead.	Good results with end to end welds, tearing apart in the case of angle welds.	50 % or more for stringers.	No.	Road bridges have been encased and have given every satisfaction. In the case of railway bridges, only the piers have been encased; the casing has been damaged a little at the heads of the piers.
...	27) Painting.	...	15 %.	...	...

SECTION VI. — Comparisons between reinforcements & replacements.

QUESTION 29. — *In your opinion how should the cost of reinforcing a bridge which has reached its theoretical limit of safety be compared with the cost of replacing the same bridge?*

What relative importance should be given to the following considerations and for what reasons?

a) *Direct cost of obtaining and putting into place the new metal;*

b) *Indirect costs (reinforcement causes a longer disturbance which may involve speed restrictions, diversion of certain traffic, and sometimes expensive temporary works; replacement causes a bigger disturbance at the time but it does not last so long, etc.);*

c) *Future expenses (replacement gives a more homogeneous bridge, with a longer expectation of life; in the case of a reinforced bridge other parts not reinforced this time may have to be in the near future, etc.).*

Give examples in which you have made detailed comparisons of these costs.

QUESTION 30. — *What allowance should be made for exceptional circumstances in the above comparisons, for example shortage of materials, too short intervals between trains and shortage of skilled labour to undertake a large amount of repair work at one and same time, rapid fluctuations in the value of money, etc.?*

QUESTION 31. — *Under such exceptional circumstances what less costly or quicker operating methods have you adopted or considered to assure the line remaining in service (for example, temporary intermediate supports, speed restrictions or load restrictions, etc.)? Give your reasons and the time during which you consider such measures will meet requirements.*

ADMINISTRATION.	QUESTION NO.		
	29	30	31
Austria	In view of the age of bridges too weak for the loads, their replacement alone is envisaged.	...	Speed and load restrictions. Provisional supports.
Belgium & Colony.			
S. N. C. B. . . .	Replacement is better than reinforcement (there are not many large bridges).	...	...
Spain	The question of reinforcement only concerns steel bridges; reinforcement is only considered if the direct cost is less than half that of replacing the bridge.	...	Shoring, reduction of loads and speeds.

ADMINISTRATION.	QUESTION No.		
	29	30	31
Finland	At the present time only the cost of the material and the delay is taken into account; replacement entails less bother and costs less in the future.	...	Limiting the speed and tonnage.
France & Colonies. S. N. C. F. . . .	It is not possible to give figures for all details of certain costs and each case should be decided on its own merits. Replacement is often more advantageous than it appears at first sight : as reinforcement often involves replacing parts not budgeted for at first, the upset to the traffic is greater, and the new bridge will be safer as far as corrosion is concerned. The availability of steel and girders from provisional bridges is another factor in favour of replacement.	...	Temporary speed and load restrictions.
Paris Metro. . .	Since operating conditions make it impossible to replace large bridges, these have to be reinforced; it is only exceptionally that local circumstances enable the traffic to be worked whilst a bridge is being removed. It is the lower immediate expenditure that determines the method adopted.	...	...
Algerian Rys. . .	...	...	Speed restrictions. Prohibition of too heavy locomotives.
Gafsa Rys. . . .	Replacement is more expensive than reinforcement. A comparison of the costs shows that in the case of bridges less than 15 m. (49′ 2½″) long, it is possible to take them up and replace them by an auxiliary bridge; taking them to the shops to be reinforced and then re-erecting them is the most advantageous solution.	The available metal is re-used as quickly as possible.	Speed restrictions for as short a time as possible, when replacement or reinforcement is finally necessary.

ADMINISTRATION.	QUESTION No.		
	29	30	31
Tunisian Rys. .	When possible, reinforcement is more economical.	Under present circumstances we are unable to reinforce or replace even damaged bridges; provisional work is the order of the day.	Transport of bridges from branch lines. Alteration of metric gauge bridges to take standard gauge track.
Djibouti to Addis-Ababa . . .	...	...	...
Greece	The bridge is replaced when the cost of reinforcement exceeds 60 % of the cost of replacement.	...	...
Holland	There are few doubtful cases. A comparison must be made of the total cost A of reinforcement (direct expenses, indirect and future costs) thanks to which the structure will last a further *n* years with the cost B of replacement (direct expenses, indirect and future costs). Under stable economic conditions with the first hypothesis after *n* years we have (B — A) plus interest and in the second, B less the amortisation costs.	Reinforcement uses less material, and will be more often adopted than in normal times.	A provisional bridge with supports good for a long period will first of all be replaced by a reconstituted bridge; speed and tonnage restrictions can be enforced for a fairly long time without serious inconvenience.
Portugal	It is estimated that the metal used for reinforcements costs at least 40 % more than that used for replacement and that the life of the reinforced structure is half that of a new bridge. The indirect costs are taken into account in each case. In principle small bridges which are no longer strong enough are replaced, and not reinforced.	The difficulty of collecting sufficient materials and labour affects the choice of a solution which can be carried out with the shortest possible delay.	...

Administration.	Question No.		
	29	30	31
Rumania	Additional metal costs twice as much as replacement metal. Generally any reinforcement involving 20 % of the weight of new metal is a costly proposition, taking into account the technical compromise involved.	The rapidity with which the bridge can be made to take the necessary loads overrides all other considerations.	Properly erected provisional bridges do not involve any restriction of the load but only of the speed their chief drawback is that they are easily damaged by floods and ice floes.
Sweden.			
State Rys. . . .	Account is taken of : 1) the direct costs, which usually make replacement the obvious choice; 2) if needs be, the indirect costs. It must not be forgotten that replacement enables changes and rectifications of the layout not possible with reinforcement.	The restoration programme is being cut down. The shortage of materials favours reinforcement, but the high costs compared with new bridges made of reinforced concrete limit the cases in which this is of interest; moreover there is a shortage of labour in country districts.	Individual circumstances come into play above all (intensity of traffic, cost of restrictions, desire to avoid the discouraging effects of limiting the loads). Provisional supports made of wood can be used as an expediency for one or two years.
Switzerland . . .	Let P_N and P_R be the respective cost of replacement and reinforcement (direct and indirect costs), $\triangle E$ the difference of the annual maintenance costs for a reinforced bridge (which may include the cost of speed restrictions on the trains or supplementary trains) and that of a new bridge, T_R the probable life of the reinforced bridge, reinforcement can only be considered when $$P_R < P_N \frac{T_R}{67} - \triangle ET_R$$ In general reinforcement is only of interest if very limited in extent, and if it makes it possible to prolong the life of the bridge very considerably.	Replacements are limited to those bridges where reinforcement would be the most disadvantageous. If money falls in value, bridges should be rebuilt to the greatest possible extent. If money is short, reinforcement comes into the picture again, to enable the desired programme to be carried out.	Single track working on double track bridges, forbidding intermediate supports; dropping the bearing to localise the reinforcements. The addition of subtenders to compress the parts under tension is useful. The value and duration of these palliatives vary considerably.

ADMINISTRATION.	QUESTION No.		
	29	30	31
Czechoslovakia . .	At the present time it is the exception to carry out reinforcements; before the war, partial reinforcements alone were made; it was considered preferable to replace bridges rather than reinforce all the components, but financial balance sheets do not appear to have been drawn up.	...	Intermediate supports provided. Provisional bridges without much bracing are only expected to last two years, with speed restrictions. Provisional bridges with substantial cross bracing are expected to last 6 years, with speeds of 50 to 60 km. (31 to 37 miles)/h.
Turkey	...	Reinforcement is to be preferred to replacement, but the shortage of gangs makes it necessary to prepare the parts in the shops, which lengthens the time required for the job. If there is a change in money values, it is advisable to get on as quickly as can be with the materials and means available.	...

SECTION VII.

Please let us have any other observations concerning the restoration and reinforcement of metal bridges, both in connection with the points raised in the questionnaire and any others which may have been omitted.

...

[625 .241 (494)]

New flat wagons for Swiss Federal Railways.

(From The Railway Gazette, September 10, 1948.)

In 1946 and 1947, the Swiss Federal Railways placed in service an improved version of the M9-class high-capacity bogie flat wagons, which incorporates advantages over the older type, the first units of which date from 1917. The improved wagons are specially suitable for the conveyance of long irons and timber, but can also be adapted, by the addition of stanchions, to carry sawn boards, straw, hay, and similar goods. They are particularly suitable for carrying heavy types of road vehicles and military vehicles, including heavy tanks. Vehicles can be loaded and unloaded sideways or head-on; for the latter purpose the low end walls of the new wagons are hinged, folding outward, and thus forming a bridge over the buffers edging on the loading platform. Because of the particular classes of loads for which the wagons are intended, the floor has been kept as low as possible, that is, $8^{11}/_{16}$ in. lower than in the older type.

Carrying capacity.

The carrying capacity of the new wagons is 44 metric tons, but normally loads should not exceed 40 metric tons. In the older type of M9 flat wagons heavy loads had to be distributed evenly over the whole length of the floor. This is not required in the new wagon, where

the two longitudinal girders under the middle portion of the carrying platform allow heavy loads to be concentrated in the centre of the wagon, if necessary.

The carrying platform of the wagon rests on two strong longitudinal girders, two side members and connecting pieces, the whole being supported by the pins of the two bogies. The load is transmitted to the two axles of each bogie through 8 helical springs. The wood flooring of the wagon is $2^{3}/_{8}$ in. thick, and there are 9 revolving anti-coloidal stanchions on either side of the wagon; 4 large iron rings on either side have been provided for fastening tarpaulins or ropes. At either end is a folding wall $11^{13}/_{16}$ in. high and intended not only to act as a bridge for head-on loading and unloading, but also to prevent certain loads, as for instance, vehicles, from shifting longitudinally over the end edges. The old M9 wagons (Nos. 69 501 to 69 530) were provided with these end walls. The stanchions have been fitted with eyes for holding fastening ropes or chains. On one end of the wagon there is a transversal gangway with handrail and handbrake, and at each of the four corners is a strong eye for fastening towing hawsers.

The bogies are particularly plain, consisting of fabricated sheet components welded together to form the frame, which supports the brake rigging and the cast steel step-bearing for the pin. The helical springs function also as a guard plate. They allow also of a limited lateral oscillation of the frame and of the carrying platform. Each spring surrounds a strong spindle with rubber abutment intended as a safety device in case of breakage of the spring or derailment. The dia. of the wheels is 3 ft. 1 in., and the axle journals are $8^{11}/_{16}$ in. by 5 in. SKF axle bearings in cast steel monobloc axle boxes have been provided. The latter carry at their sides the stepbearings for the coil springs. Each axle-box contains two ball bearings of $9^{7}/_{16}$ in. dia. and 31 in. width.

To enable the bogie to rotate underneath the carrying platform and negotiate sharp curves or small turntables, a hydraulic lifting device has been provided, by means of which the carrying platform, as well as any load (up to the maximum load), can be raised by about $9^{1}/_{16}$ in. Originally the lifting device was not supplied with the wagons because of shortage of the necessary equipment, but the wagons are being gradually fitted with it, and it is hoped to complete the work before the end of this year. The raised platform will also enable certain loads to be handled without the aid of cranes. The hydraulic pumps of the lifting appliance have been located underneath the central portion of each bogie frame.

Draw gear of the ordinary type has been provided, but its two portions at either end of the wagons have not been linked by a connecting rod. Coupling screws of 70 *tonnes* resistance are fitted.

The wagons are fitted with compressed air brakes of the Drolshammer type, adaptable to goods train or passenger train working, and all the wheels are braked on both sides by brake blocks of ordinary construction, each block consisting of two parts.

For sideways loading and unloading of vehicles each wagon has two mobile ramps. In addition, there are three mobile ramps for head-on loading and unloading from the ground.

The main particulars of the improved M9 flat wagons are given below, and those of the older type have been added for comparison.

—	Improved M9 class	Older M9 class
Length over buffers	55 ft. 6 1/2 in.	55 ft. 6 1/2 in.
Length of loading platform (outside) (*)	51 ft. 5 3/4 in.	51 ft. 5 3/4 in.
Width of loading platform	9 ft. 0 3/16 in.	9 ft. 0 3/16 in.
Area of platform	462·8 sq. ft.	462·8 sq. ft.
Total wheelbase	41 ft. 7 11/16 in.	40 ft. 11 13/16 in.
Wheelbase of bogie	5 ft. 10 9/16 in.	6 ft. 7 1/8 in.
Distance between centres of bogies	35 ft. 8 7/8 in.	34 ft. 5 1/8 in.
Height between top of rail and centre of buffer	3 ft. 5 13/16 in.	3 ft. 5 13/16 in.
Height between top of rail and platform surface	3 ft. 9 5/8 in.	4 ft. 4 1/2 in.
Height between top of rail and top of stanchion	10 ft. 2 in.	10 ft. 2 in.
	Metric tons	Metric tons
Capacity (maximum)	44	36·75
Capacity (normal)	40	35
Tare weight	20	20

(*) Inside (new wagons, between end walls) 50 ft. 11 13/16 in.

The wagons have been built by Schweizerische Wagons- und Aufzügefabrik, of Schieren-Zurich.

[385 (06 .111]

OFFICIAL INFORMATION

ISSUED BY THE

PERMANENT COMMISSION

OF THE

International Railway Congress Association.

Meeting of the 4th December 1948 of the Permanent Commission.

The Permanent Commission of the International Railway Congress Association met on the 4th December 1948, in the Belgian National Railways Head-quarters Offices in Brussels.

***

M. DELORY, *President*, opening the meeting welcomed the many personalities present and paid a tribute to the memory of M. HENNING, former President of the Association, and of M. COLLE, Member of the Permanent Commission, deceased during last summer.

He then asked the meeting to approve the minutes of the last meeting held in Brussels on the 14th February 1948.

M. WAGNER, *(Poland)*, speaking on behalf of his country and of M. KRIZ, *(Czechoslovakia)*, stated that as the situation, described in the Minutes of the meeting of the 14th February 1948 regarding the position of Spain within the Association, remains unchanged, the Polish and Czechoslovakian delegates will only attend the present meeting as observers.

***

The PRESIDENT then informed the Meeting of the changes in the Permanent Commission since its last meeting and gave particulars of the steps taken to fill the vacancies that had occurred.

The Meeting elected the following as members of the Permanent Commission :

M. J. VANDERBORGHT, Operating Manager of the Belgian National Railways, to replace M. COLLE, deceased,

M. David BLEE, Member of the Railway Executive (British Railways) to replace Mr. W. K. WALLACE,

H. E. Abdel Megid BADR Pacha, General Manager of the Egyptian State Railways to replace H. E. Mahmoud SHAKER Mohamed Pacha,

H. E. Dr. Sayed Bey Abdel WAHID, Assistant General Manager of the Egyptian State Railways, to replace H. E. Mohamed Kamal EL KHESHEN Bey.

The complete list of the members of the Permanent Commission is given in the Appendix.

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M. DA COSTA COUVREUR, *President of the Portuguese Local Organising Commission*, gave the Meeting particulars of preparatory arrangements it had made for the *Enlarged Meeting of the Permanent Commission* to be held in Lisbon from the 1st to the 4th June next. He gave details of the programme of events and the travelling facilities granted on the Portuguese system.

M. GHILAIN, *General Secretary*, then went over the agenda of the technical programme of the Lisbon meeting and gave the final list of the reporters and special reporters for the study of questions I, II and III on the Agenda (*). He also gave particulars regarding the publication of the reports in the *Bulletin* of the Association.

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The PRESIDENT advised the Meeting that an official invitation had been received from the Italian Government and the Italian State Railways to hold a Congress in Rome in October 1950, which has been accepted.

The GENERAL SECRETARY explained that in order to draw up the agenda of this Congress which, in agreement with the Italian authorities will deal with 13 to 15 questions, an inquiry will be made without delay to ask to the members of the Permanent Commission, the Administrations and the affiliated Organisations the questions they wish to be discussed in Rome. The choice of these questions will finally be made at the Lisbon Meeting.

The Meeting approved the division as between the various countries of the mandates of the Reporters for the Rome Session.

M. DI RAIMONDO, *General Manager of the Italian State Railways*, thanked the Permanent Commission for having accepted the invitation of the Italian Government. He assured the members that they will receive a hearty welcome in Italy and will have the happiest memories of their sojourn in Rome.

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M. GHILAIN, gave particulars of the provisional accounts for the financial year 1948 (up to the 15th November 1948) as well as of the estimated budget for 1949.

To meet the financial needs, the meeting decided that the variable subscription will remain in 1949 the same as that fixed for 1948, i. e. 0.15 Gold-franc per kilometre. It will be remembered that the maximum of the variable subscription according to the Rules and Regulations can amount to one third of a gold-franc per kilometre.

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Information was also given about the changes which have occurred in the membership since the previous meeting of the 14th February.

The International Railway Congress Association at present includes 33 Governments, 8 Organisations and 117 Administrations with a total mileage of 440 000 km. (270 000 miles).

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The meeting ended after the examination of various points regarding the activities of the Association since the last meeting of the Permanent Commission.

The General Secretary, P. GHILAIN. *The President,* F. H. DELORY.

(*) The official list of questions with the names of the reporters appeared in the *Bulletin* for January 1949 (p. 82).

List of Members of the Permanent Commission

OF THE

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION

(4th December 1948).

President :

F. H. **Delory** (1), directeur général de la Société Nationale des Chemins de fer belges; 19, rue du Beau-Site, Bruxelles.

Vice-Presidents :

Goursat (2), directeur attaché à la Présidence du Conseil d'Administration de la Société Nationale des Chemins de fer français; 88, rue Saint-Lazare, Paris (IXe);

P. **Ghilain** (3), directeur du Service du Matériel et des Achats de la Société Nationale des Chemins de fer belges; 19, rue du Beau-Site, Bruxelles.

Members of the Executive Committee :

Dorges (1), inspecteur général des Ponts et Chaussées, directeur général des Chemins de fer et des Transports au Ministère des Travaux publics et des Transports; 244, boulevard Saint-Germain, Paris;

Sir Cyril **Hurcomb** (2), Chairman of the British Transport Commission; 55, Broadway, London, S. W. 1 ;

Sir Gilmour **Jenkins** (3), Secretary to Minister of Transport (Great Britain) ; Berkeley Square House, Berkeley Square, London, W. 1.

Ex-presidents of session, members ex-officio :

Baron Edouard **de Rothschild**, président du Conseil d'administration de la Compagnie du Chemin de fer du Nord français; 27, avenue Bosquet, Paris;

S. E. Ibrahim Fahmy **Kerim** Pacha; Le Caire.

Dr W. **Meile**, président de la Direction générale des Chemins de fer fédéraux suisses; Berne.

Members :

S. E. Ibrahim Dossuky **Abaza** Pacha (2), Ministre des Communications d'Egypte; Le Caire;

E. **Alfonso** (2), président du Conseil d'administration du Réseau National des Chemins de fer espagnols; Madrid;

Armand (1), directeur général adjoint de la Société Nationale des Chemins de fer français; 88, rue St-Lazarre, Paris (IXe);

S. E. Abdel Megid **Badr** Pacha (1), directeur général des Chemins de fer de l'Etat égyptien ; Le Caire ;

V. M. **Barrington-Ward** (3), member of the Railway Executive (British Railways); 222, Marylebone Road, London, N. W. 1;

M. **Beevor** (2), Chief secretary and legal adviser to the British Transport Commission ; 55, Broadway, London, S. W. 1;

Besnard (3), chef de service adjoint au directeur général des Chemins de fer et des Transports, Ministère des Travaux publics et des Transports; 244, boulevard Saint-Germain, Paris;

David **Blee** (1), member of the Railway Executive (British Railways) ; 222, Marylebone Road, London, N. W. 1 ;

J. **Bouciqué** (1), directeur du Service de la Voie de la Société Nationale des Chemins de fer belges; 17, rue de Louvain, Bruxelles;

Boutet (3), inspecteur général des Ponts et Chaussées, vice-président du Conseil d'administration de la Société Nationale des Chemins de fer français; 88, rue Saint-Lazare, Paris (IXe);

O. V. **Bulleid** (1), Chief mechanical engineer, Railway Executive (British Railways-Southern Region); Waterloo Station, London, S. E. 1;

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(1) Retires at the 15th session.
(2) Retires at the 16th session.
(3) Retires at the 17th session.

R. **Claudon** (1), inspecteur général des Ponts et Chaussées, membre du Conseil d'administration de la Société Nationale des Chemins de fer français; 88, rue Saint-Lazare, Paris (IXe);

M. W. **Clement** (2), president, Pennsylvania Railroad Company; Broad Street Station Building, 1617, Pennsylvania Boulevard, Philadelphia, 4, Pa.;

Dr R. **Cottier** (2), directeur de l'Office fédéral des transports de la Confédération suisse; Berne;

R. **da Costa Couvreur** (2), président du Conseil supérieur des Travaux publics au Ministère des Travaux publics et des Communications du Portugal; Rua de S. Mamede (ao Caldas), 63, Lisbonne;

G. O. W. P. **Dahlbeck** (3), directeur général et chef des Chemins de fer de l'Etat suédois; Stockholm;

Dargeou (1), directeur du Service central du Mouvement de la Société Nationale des Chemins de fer français; 8, rue de Londres, Paris (IXe);

J. **de Aguinaga** (3), directeur général adjoint du Réseau National des Chemins de fer espagnols; Madrid;

Ing. V. **Dechitch** (3), Ministre adjoint des Communications de la République fédérative populaire yougoslave; Belgrade;

F. H. **Delory** (already named);

R. **de K. Maynard** (1), C. I. E. H. Q. Railway Inspectorate, Transport Group, 67, Headquarters C. C. G. Bielefeld (B.A.O.R. 15);

F. Q. **den Hollander** (2), président des Chemins de fer néerlandais, S. A.; Utrecht;

M. **Devos** (2), directeur général de la Société Nationale belge des Chemins de fer vicinaux; 14, rue de la Science, Bruxelles;

Ing. G. **di Raimondo** (2), directeur général des Chemins de fer de l'Etat Italien; Rome;

Dorges (already named);

W. T. **Farici** (1), president, Association of American Railroads; Transportation Building, Washington 6. D. C.;

S. E. El Sayed **Gawdat** Bey (1), sous-secrétaire d'Etat au Ministère des Communications d'Egypte; Le Caire;

P. **Ghilain** (already named);

Goursat (already named);

Ranald J. **Harvey** (1), consulting engineer to the Government of New Zealand; 34, Victoria Street, Westminster, London, S. W. 1;

Sir Cyril **Hurcomb** (already named);

Sir Gilmour **Jenkins** (already named);

Ing. Ch. **Kalitzov** (3), chef de la Section du mouvement des Chemins de fer et des Ports de l'Etat bulgare; Sofia;

A. **Kriz** (1), ingénieur, conseiller supérieur de Section au Ministère des Communications de la République tchécoslovaque; Prague;

Dr N. **Laloni** (2), chef du Service Commercial et du Trafic des Chemins de fer de l'Etat italien; Rome;

Lemaire (3), directeur général de la Société Nationale des Chemins de fer français; 88, rue Saint-Lazare, Paris (IXe);

R. **Lévi** (3), directeur du Service central des Installations fixes et de la Construction de la Société Nationale des Chemins de fer français; 42, rue de Châteaudun, Paris;

C. **Lucchini** (3), directeur général des Chemins de fer fédéraux suisses; Berne;

Ing. R. **Luna** (3), directeur général des Chemins de fer de l'Etat argentin; Buenos-Aires;

M. **Malderez** (3), secrétaire général du Ministère des Communications de Belgique; 17A, rue de la Loi, Bruxelles;

A. **Marguerat** (2), directeur des Compagnies de Chemins de fer de Viège à Zermatt, Furka-Oberalp, Gornergrat et Schöllenen; Lausanne;

Ing. F. **Marin** (1), vice-directeur général des Chemins de fer de l'Etat italien; Rome;

Ing. P. P. **Martin** (2), inspecteur général de l'Exploitation commerciale, sous-directeur des Chemins de fer de l'Etat argentin; Buenos-Aires;

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(1) Retires at the 15th session.
(2) Retires at the 16th session.
(3) Retires at the 17th session.

Dr W. **Meile** (already named);

Ing. E. **Mellini** (2), inspecteur général technique de surveillance à l'Inspectorat Général de la motorisation civile et des transports concédés; Rome;

Sir Eustace **Missenden** (2), Chairman of the Railway Executive (British Railways); 222, Marylebone Road, London, N. W. 1;

Sir Alan **Mount** (3), Chief inspecting officer of Railways, Ministry of Transport; Berkeley Square House, Berkeley Square, London W. 1;

P. **Nolet de Brauwere** (1), Secrétaire Général de la Société Nationale des Chemins de fer belges ; 17, rue de Louvain, Bruxelles ;

J. H. **Nueile** (1), president, Delaware & Hudson Railroad Corporation; 32, Nassau Street, New York City;

G. **Olivier** (2), directeur général adjoint de la Société Nationale des Chemins de fer belges; 17, rue de Louvain, Bruxelles;

G. **Pader** (2), secrétaire général de l'Union internationale des chemins de fer; 10, rue de Prony, Paris;

Dr W. **Rauscher** (1), conseiller ministériel, directeur général adjoint et directeur du Service Commercial des Chemins de fer fédéraux autrichiens; Elisabethstrasse, 9, Vienne;

J. M. **Rivero de Aguilar** (1), directeur général du Réseau National des Chemins de fer espagnols; Madrid;

F. **Steiner** (3), Vice-directeur de l'Office fédéral des transports; Berne;

E. D. **Terkelsen** (1), directeur général des Chemins de fer de l'Etat danois; 40, Sölvgade, Copenhague, K;

J. C. L. **Train** (3), member of the Railway Executive (British Railways); 222, Marylebone Road, London, N. W. 1;

J. **Vanderborght** (2), directeur du Service de l'Exploitation de la Société Nationale des Chemins de fer belges ; 17, rue de Louvain, Bruxelles ;

Th. M. B. **van Marle** (1), inspecteur-generaal van het Verkeer, Rijksverkeersinspectie; La Haye;

L. **Varga** (2), président de la Direction des Chemins de fer de l'Etat hongrois; Budapest;

F. Perez **Villamil** (3), sous-directeur général du Réseau National des Chemins de fer espagnols; Madrid;

Wagner (2), ingénieur en chef au Ministère des Communications de Pologne; Varsovie;

S. E. Dr Sayed Bey Abdel **Wahid** (1), directeur général-adjoint des Chemins de fer de l'Etat égyptien ; Le Caire ;

Dr C. C. **Wang** (3), representative of Chinese Ministry of Communications; 21, Tothill Street, Westminster, London, S. W. 1;

H. D. **Ward Smith** (1), advisory engineer to the High Commissioner for the Union of South Africa; South Africa House, Trafalgar Square, London W. C. 2;

R. B. **White** (2), president, Baltimore & Ohio Railroad Company; Baltimore, Md.;

G. **Willaert** (3), conseiller à la Direction Générale de la Société Nationale des Chemins de fer belges; 17, rue de Louvain, Bruxelles;

N... (3) (Rumania).

Honorary member : U. **Lamalle,** directeur général honoraire de la Société Nationale des Chemins de fer belges, professeur de cours de chemins de fer à l'Université de Louvain; 175, avenue Winston Churchill, Uccle-Bruxelles.

SECRETARY'S OFFICE : 19, rue du Beau Site, Brussels.

General Secretary : P. **Ghilain** (already named).

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(1) Retires at the 15th session.
(2) Retires at the 16th session.
(3) Retires at the 17th session.

NEW BOOKS AND PUBLICATIONS.

[385 .02]

The Universal Directory of Railway Officials and Railway Year Book, 1948-1949. — London : The Directory Publishing Company Limited, 33, Tothill Street, Westminster, S. W. 1. — 618 pages ($8\,^1/_2 \times 5\,^1/_2$ in.). (Price : 30 s. net.)

The Universal Directory of Railway Officials and Railway Year Book 1948-1949 reaches with the present volume its 54th year of publication.

The first edition was compiled from official sources and issued in 1895, and at that time some 270 pages sufficed to cover the text including an index to countries, an index to names of railways and the comprehensive personal index of railway officials which is still a noteworthy feature of the volume.

The present edition should prove at least as valuable as its predecessors in containing within the scope of little more than 600 carefully-condensed pages more comprehensive lists of officers and particulars of railways throughout the world than can be obtained from any other publication in any language.

The information contained in this volume enables railway officers and others to keep in touch with the personnel on railways throughout the world for the exchange of information concerning research and developments in all phases of railway operation and maintenance.

Nationalisation of the railways in Great Britain and in other parts of the world as well as political changes which have affected the status of many parts of the British Commonwealth have necessitated to recast the whole of the early section of the book and the order of the entries into two main divisions, namely, British Commonwealth and Foreign. Each of these sections is again subdivided geographically into Continents as follows :

Europe, Australia and New Zealand,
Asia, North America,
Africa, South and Central America.

For ready reference purposes at the end of the volume will be found three indexes :

1) an index to countries;

2) a general index including all references to railways and statistical and other information;

3) a personal index of railway officials.

[385. (09 (.45)]

Le Ferrovie Italiane dello Stato rinascono. La Ricostruzione fino all' aprile 1948. — *(The Reconstruction of the Italian State Railways.* — Progress as at the end of April 1948). One brochure ($8\,^1/_4 \times 11\,^{13}/_{16}$ inches) of 48 pages, copiously illustrated. — 1948, Roma, Ufficio Stampa del Ministero dei Trasporti.

A new chapter in the reconstruction of the Italian State Railways is written in this book. In May 1947, the Management carried out a general examination and was able to record important progress as well as favourable indications of a resumption of activity. The *Ingegneria Ferroviaria* has published a book on the subject under the title of « *La Ricostruzione delle Ferrovie Italiane dello Stato* », which was reviewed here (*Bulletin* of August 1948). This des-

cribes the progress made during the course of a year.

In the case of each kind of equipment or material the considerable damage caused by the war is recalled. A brief note gives the broad outlines of the steps taken to restore them. A comparison is made by means of figures and diagrams between the available resources at the end of April 1948 and those available in 1939 and 1945. Drawings show characteristic restorations and new realisations side by side with the ruins and war damage.

As was to be expected, progress has been faster in certain sections, either because the difficulties were less or because a greater effort was felt to be justified. Thus 82 % of the electrified lines, 90 % of which were out of action, have been restored, and the stock of electric locomotives which had fallen from 1 531 to 512 has now reached 1 262.

Various circumstances have had to be taken into account in the reconstruction work, such as the shortage of iron for bridges and on the other hand the lessons taught by experience have been put to good use. Innovations have been introduced or are proposed.

In order to economise the use of iron, many metal structures have been replaced by masonry or reinforced concrete bridges. Those which had to be kept have been made of 50 kgr. (110 lbs.) steel instead of soft steel. The use of reinforced concrete has been extended. In the case of track equipment, welding has been used for repair work as well as to increase the length of rails to 36 m. (118 feet) in the open and 108 m. (354 feet) in tunnels.

Points and signals will in future be worked by central control by means of route levers entirely electrically, without any mechanical interlocking. The new signalling regulations make provision for the use of light signals which are already in use on the most important lines.

As regards electric traction, the preference is for direct three phase current. The electric trains and electric railcars, like the rolling stock in general, suffered a lot from the war, to the extent of some 82 %. The improvements made to the new trains will help to compensate for this. It will be the same in the case of passenger coaches and goods wagons.

The various notes given make it possible to estimate the ground covered and appreciate the innovations made in the reconstruction of station buildings, housing for the staff, tunnels, electric power stations and substations, steam locomotives, railcars, locomotive sheds, and trial vehicles. These are grouped together in a numerical table which also gives the future programme, from which it appears that in 1950 the number of direct current electric locomotives will be 140 % of the 1943 stock, the electrotrains will reach the proportion of 171 % whereas three phase locomotives and steam locomotives will have fallen off in number.

To estimate the increasing efficiency of the railway equipment, it is necessary to consult the graphs relating to the services, traffic and receipts. These give the author a chance to stress the fact that the receipts for both passenger and goods traffic have increased to a greater extent than the coefficient of the increased tariffs.

There is an introductory note by the General Manager of the Italian State Railways, Mr. Giovanni DI RAIMONDO. This is an eloquent testimonial to the essential part played by the railway in the economic life and recovery of the country, and a tribute to the magnitude of the task accomplished by the Italian railwaymen, and to their devotion and patriotism.

E. M.

[341. 324 (43)]

BREAUD (H.). Ex-Directeur de la Régie des Chemins de fer des Territoires Occupés. — **La Régie des Chemins de fer des Territoires Occupés, 1923-1924** *(The Management of the Railways in the Occupied Territory,* 1923-1924.). — One volume ($7\,^{7}/_{8} \times 10\,^{3}/_{4}$ inches) of 606 pages with figures and maps. — 1938, Paris, Presses de l'Imprimerie Chaix.

In the spring of the year 1923, it was learnt that Belgian railwaymen were leaving for Germany where together with French railwaymen they were going to operate the railways of the Ruhr. The news was not altogether a surprise, especially to those who were well informed regarding the international situation. Nonetheless it produced a great impression. It appeared to be a very bold undertaking, and those who dared to undertake it had to have plenty of courage apart from other qualities.

After a quarter of a century, the book written by M. BRÉAUD who was the Manager of the *Railways of the Occupied Territory (R.C.F.T.O.)* brings back the atmosphere of the period. He recalls the events which justified the intervention of the French and Belgian allies. This took the form of setting up a real railway management. The circumstances in which it was born and functioned make it a unique fact in the annals of railway history. Consequently its history deserved to be written and it was fitting that it should be written by someone with special qualifications.

To try and analyse the work is to risk diminishing its value. At the most it is only possible to insist on the vastness of the subject. Here we have the complete tale of the restoration and operation by foreigners of a railway abandoned by its own employees, who had helped to complete its ruin. In the end the management extended to 5 251 km.. (3 262 miles) of lines, serving the most highly industrialised part of Germany, where 170 000 German railwaymen had been previously employed.

These figures, striking as they are, are insufficient to give an idea of the enormous task with which the Allies were faced. M. BRÉAUD's able pen paints an imposing picture of the innumerable difficulties of all kinds which his colleagues encountered as soon as they arrived, which continued to multiply throughout the whole period. How the French and Belgian railwaymen reacted, how out of the chaos of tangled and sabotaged lines, with all the safety equipment out of action and of unknown systems, without documentation, with faulty or inadequate stock, how out of all this they made a coherent railway system, with its proper administration and technique, its shops and commercial services, is told by the author in some 500 pages very movingly. He tells his tale with the authority of a leader who has seen his characters tested and at work and has shared their difficulties, so that all he had to do was to make his choice from the abundant material at his diposal.

There were many remarkable things in the life of the railway management, which short as it was does not deserve to be forgotten. But amongst the often dramatic happenings with which the book is filled, the fact that must be stressed is the complete success of the venture. All the objects in view were achieved, and even exceeded. First of all they had to assure the military transport and reparations transport. The testimonials reported from the authorities concerned are very eloquent in this respect. It was also imperative that the railway should not be a burden on the Allied Governments, and care had to be taken that the paralysing of

civilian transport did not lead to a situation which might be used as a weapon against the occupiers of the country. Here the statistics are very enlightening. The growth of the figures for the services and traffic show how soon the railway represented a triumph for its technique and organisation. On the financial plane, there was another difficulty, the rapid depreciation of the currency. A very original and efficacious means was found of overcoming this. At the end of the third book dealing with the liquidation of the railway, we are given the final balance : 576 million French francs.

M. BRÉAUD has had a double object in view. He wished to make known the facts so that the achievements and methods used might serve to provide valuable information. But he also wished to pay a tribute to the French and Belgian railwaymen, a tribute justly due to them on account of the moral and professional qualities of which they gave such ample proof. He could pay them no better homage than this objective report of what they accomplished. Those who took part in the work will read the book with understandable interest. The affair was brought to a completely successful end whereas its critics expected it to fail. The results obtained were also due in part, to a greater extent than the author shows, to the personal actions of the Manager of the railway.

E. M.